**WIN**
A SKY-WATCHER TELESCOPE WORTH
**£259**

WHY IT'S NOT THE END FOR CASSINI

# All About Space

DEEP SP EM | EXPLORATION

## 72 HOURS UNTIL IMPACT

The all-new plan to protect Earth from an asteroid

## NASA NEEDS YOU!

Get involved without leaving home

**NEIL DEGRASSE TYSON**

# "PLUTO'S NOT A PLANET. GET OVER IT!"

The no-nonsense astrophysicist's thoughts on the universe, American space program fears and George R. R. Martin

Why Elon Musk predicts failure at launch

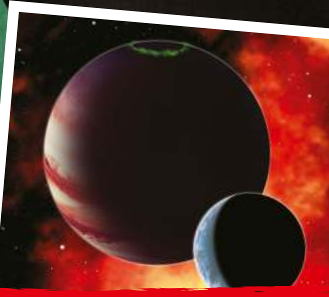
## SPACEX'S HEAVIEST ROCKET

Future

ISSUE 069

## EXOMOON FOUND?

Its discoverer has all the details



+ **SMARTPHONE ASTROPHOTOGRAPHY** • AURORAE ON OTHER PLANETS • **ESTIMATE STAR BRIGHTNESSES**

# POWERBALL® GYROSCOPES

DEVELOP YOUR OWN GRAVITATIONAL FORCES...LIKE TINY SPINNING PLANETS

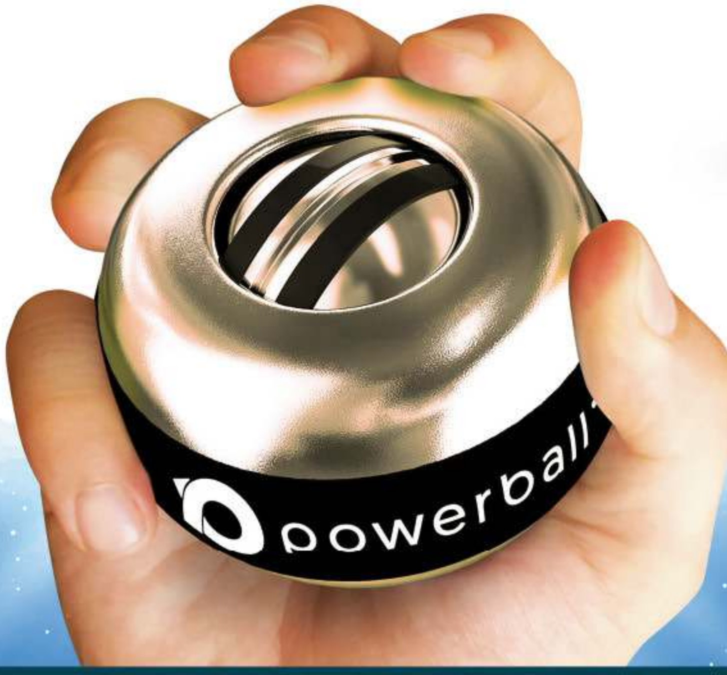
**280 Classic**
The Entry One £19.99

**280 Autostart Classic**
The All Round One £29.99

**280 Signature Pro**
The Exquisite One £39.99

**280 Autostart Pro**
The Best Selling One £44.99

**Titan**
The Most Powerful One £129.99



**280 Autostart Fusion**
The Amazing One £49.99

powerballs.com

A zero gravitational training aid for NASA astronauts, Powerball® delivers strengthening and rehabilitation for the arms & wrists unlike anything else on *(or off)* this planet. But don't spin it too fast...or you just might create a black hole!

@ Tobias Roetsch

The Cassini mission impacted Saturn this month

# Welcome to issue 69!

After 13 years, an enormous amount of findings and a whole catalogue of images of the Saturn system, the Cassini mission has come to an end by making a dive into the ringed planet's atmosphere. While it created an event to remember as the spacecraft met its fiery end, it's not over for the NASA mission, which launched during the autumn of 1997 on board a Titan IVB/Centaur to the outer Solar System. Head on over to page 58 to find out why there's still a treasure trove of discoveries and new information to glean from Cassini.

Beyond Saturn, dwarf planet Pluto has been the focus of our cover star's attention this month. Whether you think the world within the Kuiper Belt should be reinstated to planet status or not, astrophysicist Neil deGrasse Tyson shares his thoughts on not just the 2006 decision of the International Astronomical Union, but the entire state of our universe (for example, are we living in a simulation?), his fears for the American space program as well as the computer game that he's currently working on with none other than *Game of Thrones* creator George R. R. Martin.

This month, we meet the astronomer who thinks he may have found the very first exomoon, uncover what we'll do if our planet is about to be impacted by an asteroid or comet within 72 hours and find out more about the likelihood that we've already collided with the Andromeda Galaxy – and how it will change the universe's laws. See you again on 12 October!

**Gemma Lavender**
Editor

> "The spacecraft will break apart and burn up like a meteor within a couple of minutes after losing contact" **Preston Dyches, page 58**

## Our contributors include...

**Libby Plummer**
*Science and technology journalist*
We've got 72 hours until an asteroid impacts our planet – what will we do? Libby has the details on the all-new action plan to save humanity on page 28

**Luis Villazon**
*Science and technology writer*
Luis discovers that NASA's Cassini mission at Saturn may have come to an impressive end, but that doesn't mean its over. Find out how on page 58.

**Giles Sparrow**
*Book author & journalist*
Our galaxy could have already collided with our nearest spiral, Andromeda. Giles speaks to the scientists with the evidence, and reveals how it could question physics.

**Stuart Atkinson**
*Astronomer & author*
Did you know that you can use data from the likes of Juno and Curiosity to create your own space images? Stuart and some prolific image processors reveal how it's done.

## Keep up to date

**Online**
www.spaceanswers.com

**Facebook**
/AllAboutSpaceMagazine

**Twitter**
@spaceanswers

# CONTENTS

**TWEET US**
@spaceanswers

**POST ON FACEBOOK**
/AllAboutSpaceMagazine

**SEND US AN EMAIL**
@spaceanswers.com

www.spaceanswers.c

## LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

06 Snow on the Red Planet, TRAPPIST-1's planets could have the same habitability prospects as Mars and Hubble releases more stunning images of the universe

## FEATURES

16 **Neil deGrasse Tyson**
The no-nonsense astrophysicist's thoughts on the universe, U.S. space program and George R. R. Martin

24 **User Manual**
**NuSTAR**
Your guide to the ground-breaking X-ray telescope

28 **72 hours until impact**
The all-new action plan to save humanity from extinction

36 **Future Tech**
**Spinning a space station**
A private company has a machine that could weave the space structures of your dreams

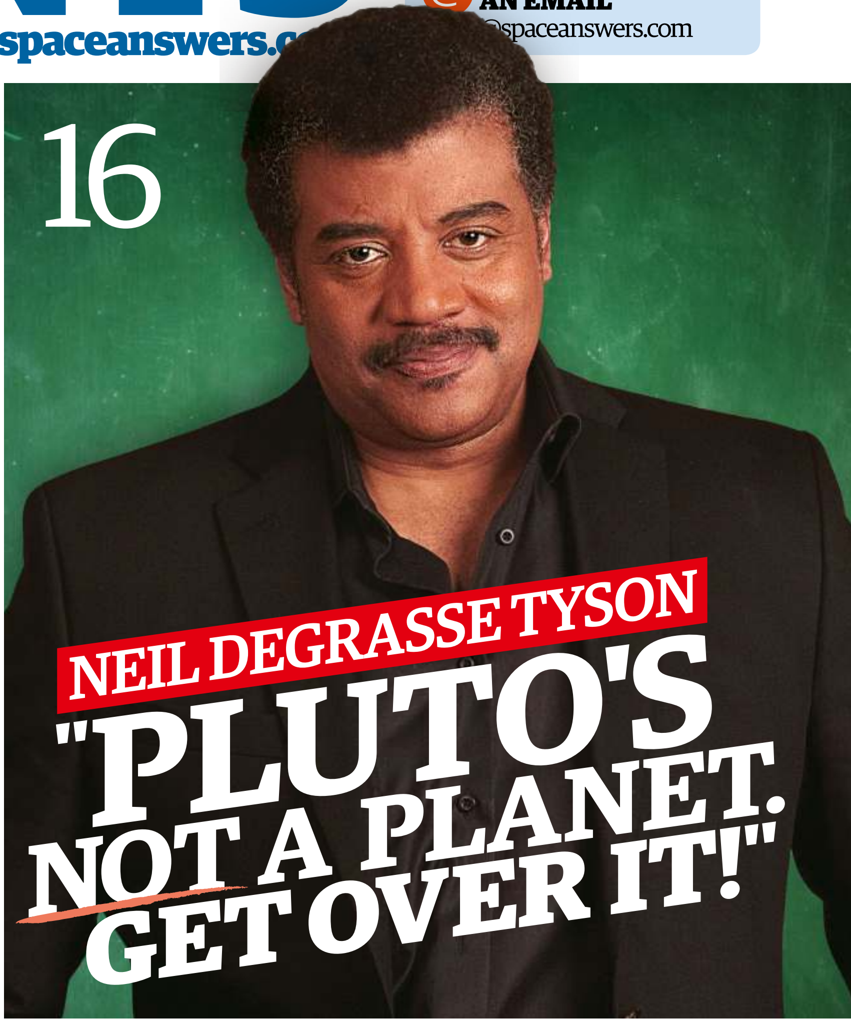
38 **Have we already crashed into Andromeda?**
Billions of years from now, our galaxy and our nearest spiral will collide. According to recent research, it could be a case of history repeating itself

46 **Interview**
**Have we found an exomoon?**
Alex Teachey reveals if we should be getting our hopes up about exomoon discovery

58 **Why it's not the end for Cassini**
After 13 years around Saturn, the spacecraft's job is over, but there are still discoveries to be made

66 **Focus On**
**Space X... we have a problem**
Why SpaceX CEO Elon Musk predicts failure at launch for the Falcon Heavy rocket

68 **Imaging from spacecraft data**
The space agencies need you! Find out how you can contribute to science without leaving home



16

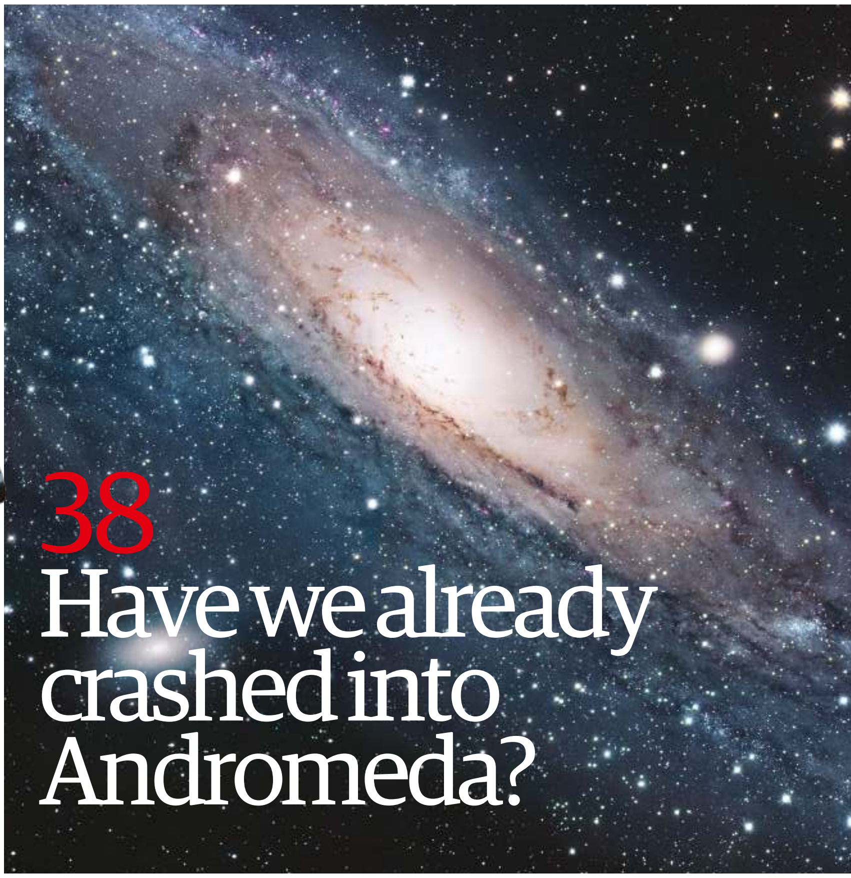
NEIL DEGRASSE TYSON

"PLUTO'S NOT A PLANET. GET OVER IT!"

94

WIN!

A SKY-WATCHER EVOSTAR-90

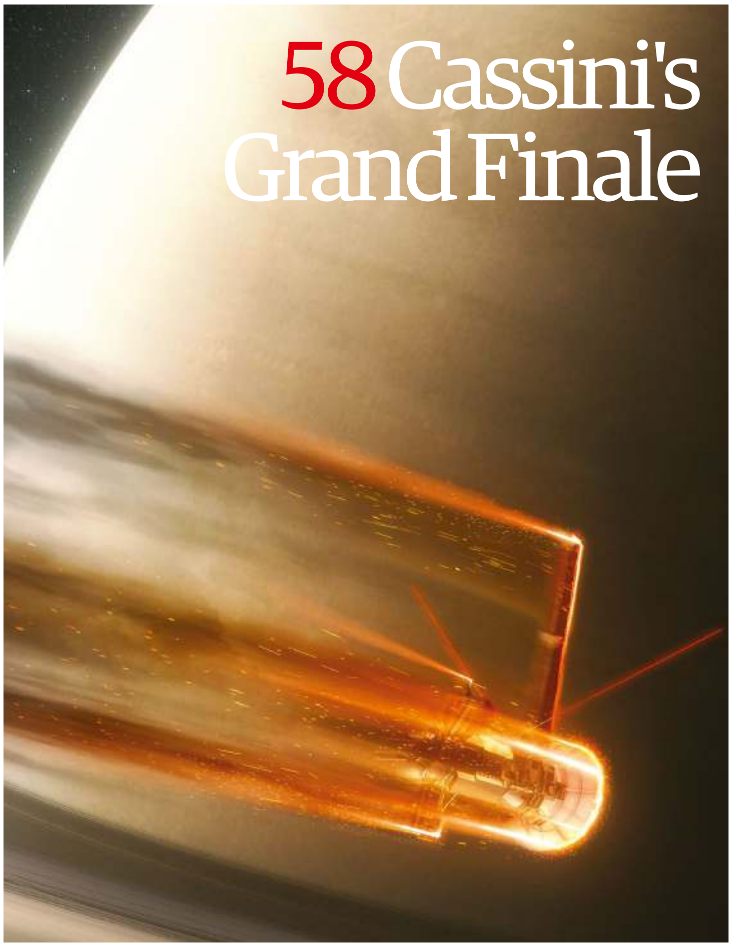


38

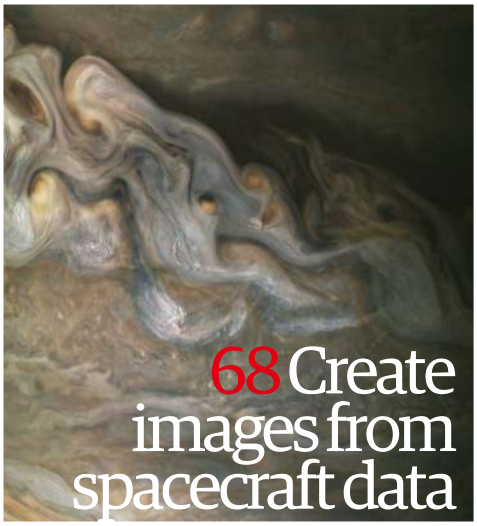
Have we already crashed into Andromeda?

> "It's going to be tricky. I think we're going to have to get even cleverer about how we detect exomoons"

46 Alex Teachey
Columbia University Department of Astronomy



## 58 Cassini's Grand Finale



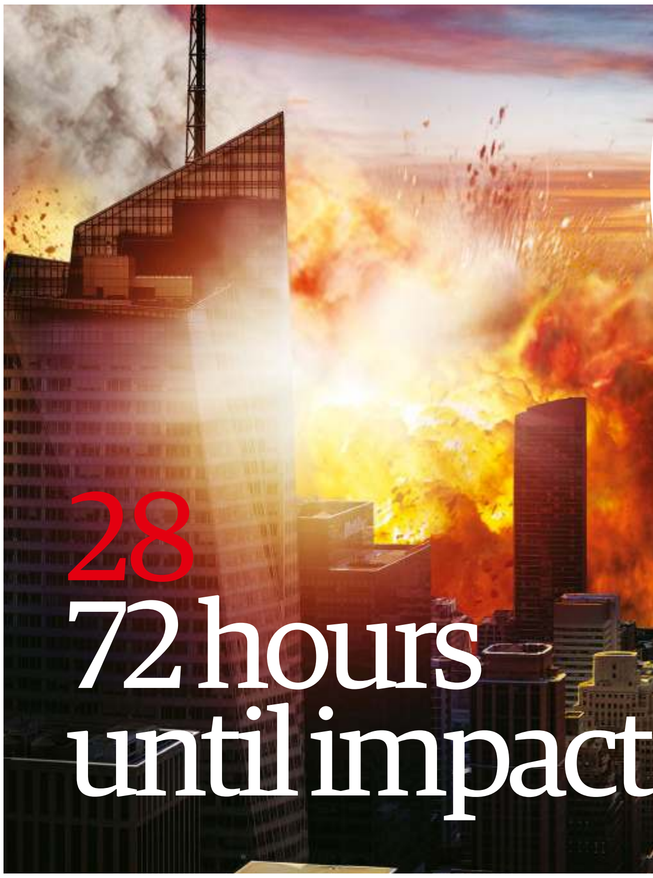
## 68 Create images from spacecraft data

Space ANSWERS

## 52 Your questions answered

Our experts solve your space conundrums this issue

## 24 NuSTAR



## 28 72 hours until impact

## STARGAZER

Your complete guide to the night sky

74 **What's in the sky?**
Don't miss some great astronomical sights this month

78 **Month's planets**
Venus dazzles in the dawn sky - don't miss it!

80 **Moon tour**
Find one of our lunar companion's largest craters, made famous by science fiction

81 **Naked eye & binocular targets**
Look east on clear autumn nights and you'll be able to spot a demonic star

82 **How to... Estimate star magnitudes**
Work out how bright objects really are in the night sky

84 **Deep sky challenge**
Among the riches for deep sky observers, there's galaxies, nebulae and star clusters galore

86 **How to... Photograph the planets with your smartphone**
Your guide to shooting the Solar System with minimal equipment

88 **The Northern Hemisphere**
Aquarius and Pegasus grace the skies of late September

96 **In the shops**
We test the latest telescopes, kit and accessories before you buy

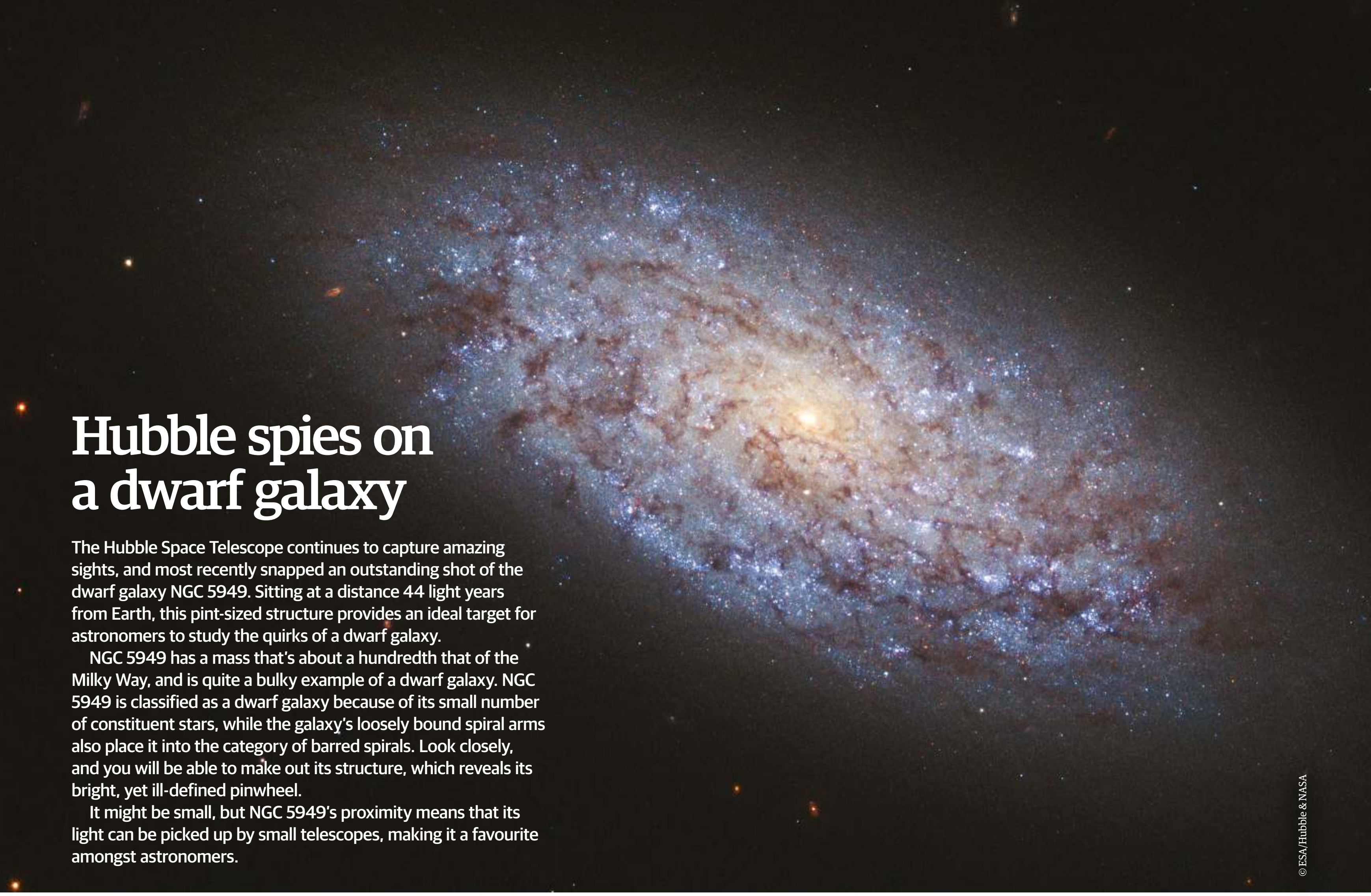
Visit the **All About Space** online shop at
**www.myfavouritemagazines**.co.uk
For back issues, books, merchandise and more

**FREE HAYNES MANUAL**
Page 50

# Expedition 52 commences

Expedition 52 has officially begun, as these three astronauts have arrived at the International Space Station (ISS), where they will stay for the next four and a half months to conduct groundbreaking experiments. NASA's Randy Bresnik (top), European Space Agency's Paolo Nespoli (middle) and Roscosmos cosmonaut Sergey Ryazansky (bottom) are pictured here waving goodbye before they board the Soyuz MS-05 rocket, which was launched on 28 July 2017 (top image). Once they had settled on the Space Station, Bresnik had the chance to check out the new, experimental Bigelow Expandable Aerospace Module, also known as BEAM (bottom image), which provides astronauts with a comfortable area to live and work while protecting them from space radiation and other elements in the space environment.

© NASA/Joel Kowsky; ESA-Manuel Pedoussaut;



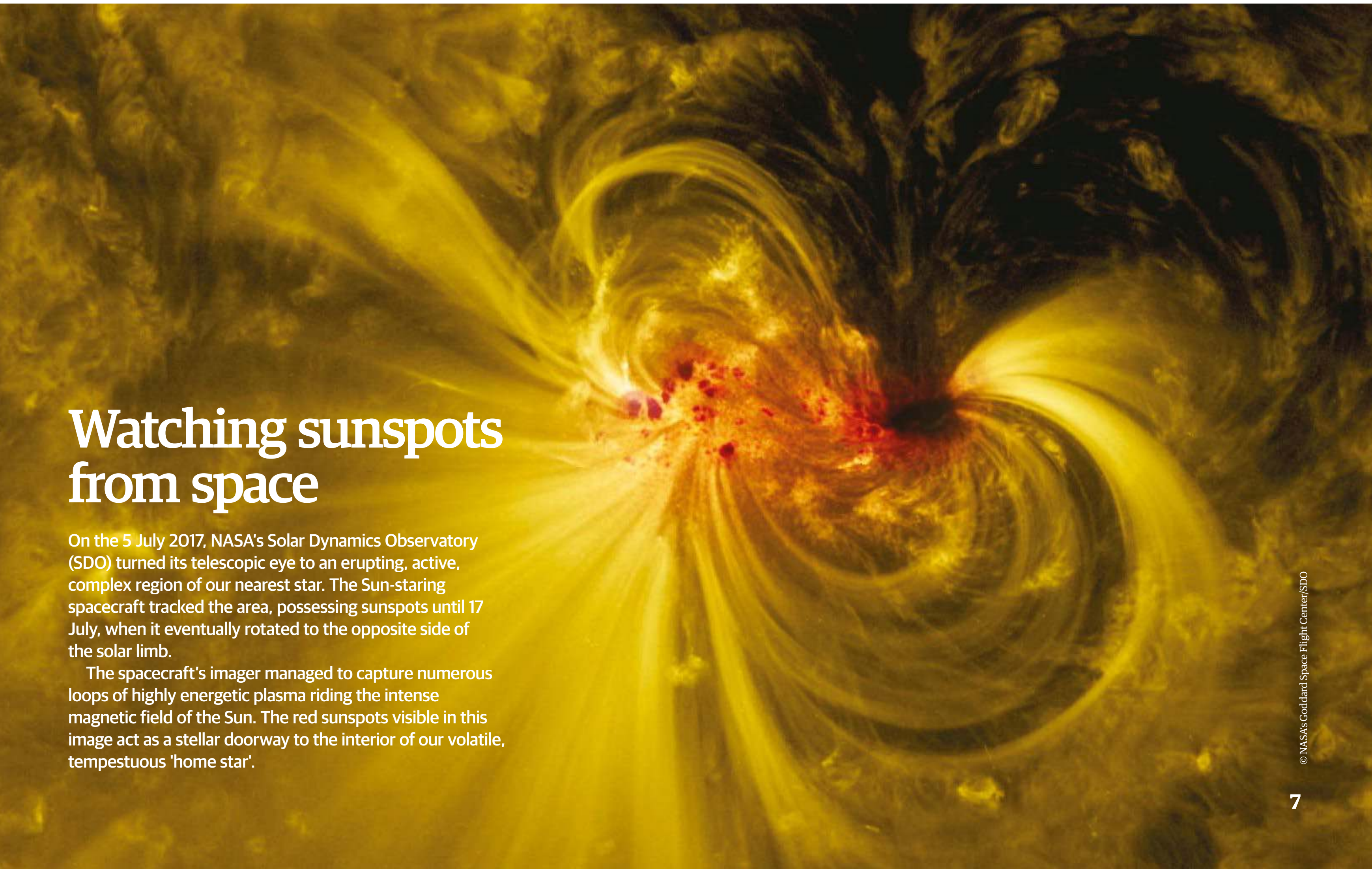
# Hubble spies on a dwarf galaxy

The Hubble Space Telescope continues to capture amazing sights, and most recently snapped an outstanding shot of the dwarf galaxy NGC 5949. Sitting at a distance 44 light years from Earth, this pint-sized structure provides an ideal target for astronomers to study the quirks of a dwarf galaxy.

NGC 5949 has a mass that's about a hundredth that of the Milky Way, and is quite a bulky example of a dwarf galaxy. NGC 5949 is classified as a dwarf galaxy because of its small number of constituent stars, while the galaxy's loosely bound spiral arms also place it into the category of barred spirals. Look closely, and you will be able to make out its structure, which reveals its bright, yet ill-defined pinwheel.

It might be small, but NGC 5949's proximity means that its light can be picked up by small telescopes, making it a favourite amongst astronomers.

© ESA/Hubble & NASA

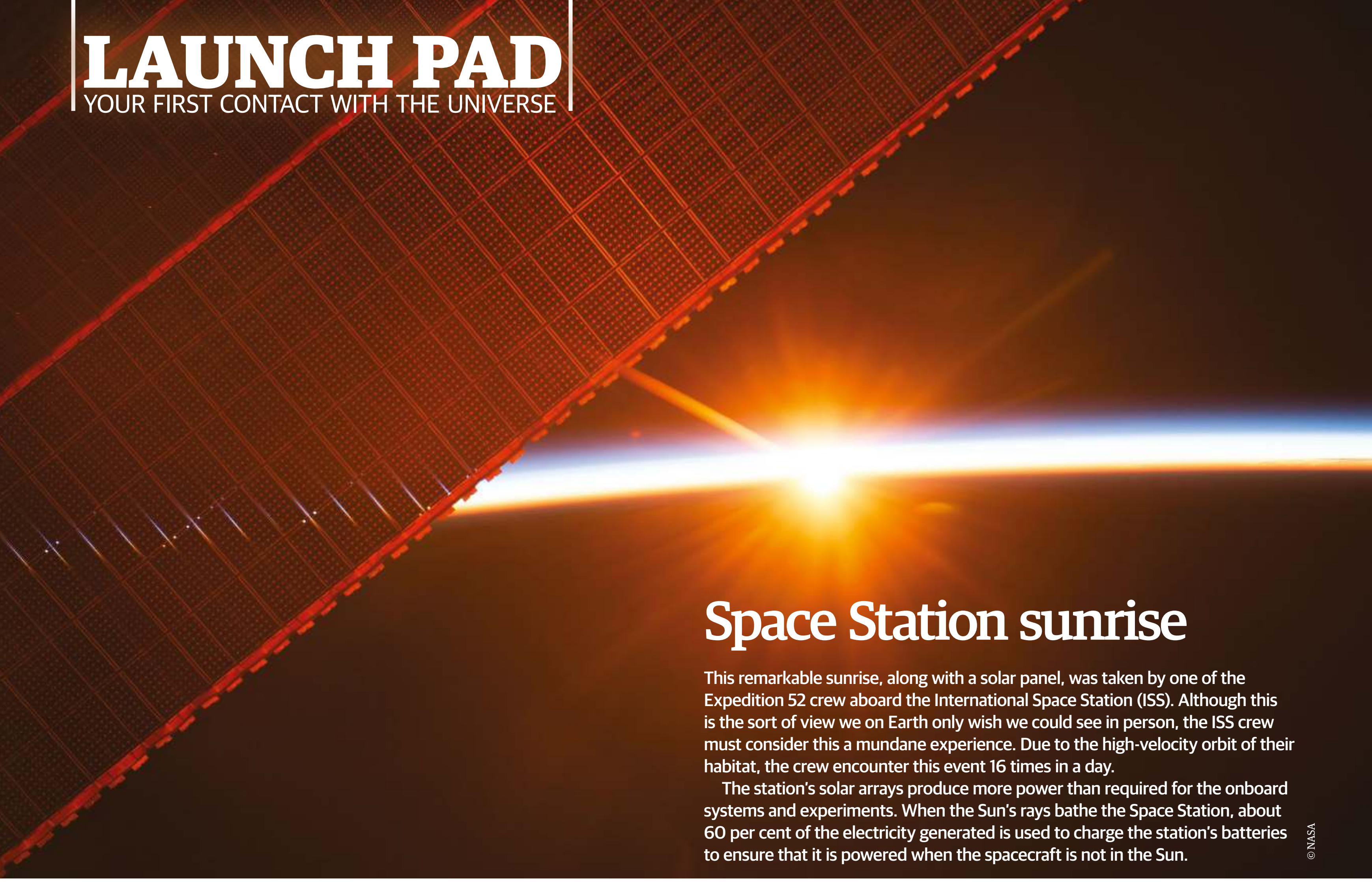


# Watching sunspots from space

On the 5 July 2017, NASA's Solar Dynamics Observatory (SDO) turned its telescopic eye to an erupting, active, complex region of our nearest star. The Sun-staring spacecraft tracked the area, possessing sunspots until 17 July, when it eventually rotated to the opposite side of the solar limb.

The spacecraft's imager managed to capture numerous loops of highly energetic plasma riding the intense magnetic field of the Sun. The red sunspots visible in this image act as a stellar doorway to the interior of our volatile, tempestuous 'home star'.

© NASA's Goddard Space Flight Center/SDO

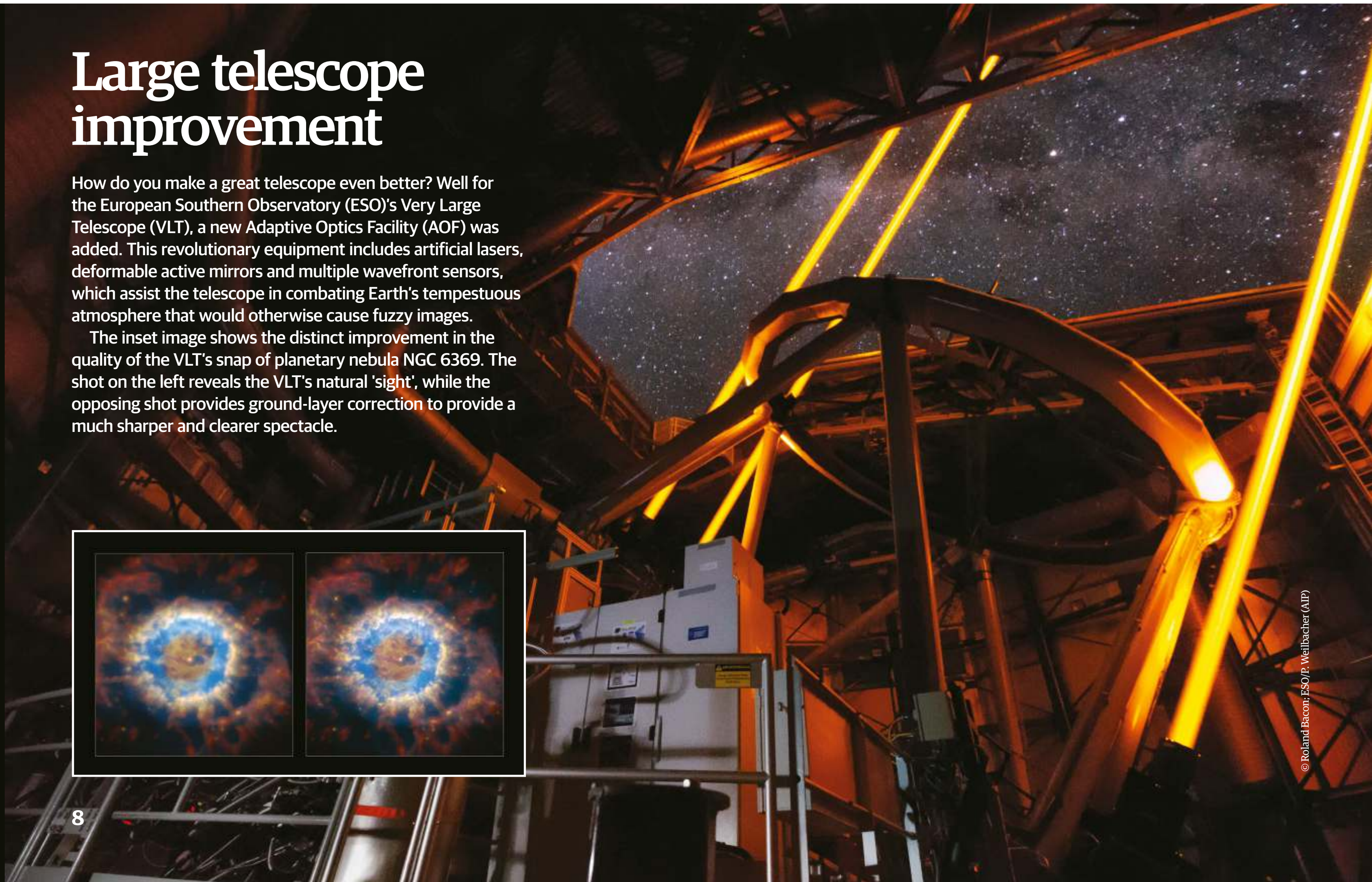


## Space Station sunrise

This remarkable sunrise, along with a solar panel, was taken by one of the Expedition 52 crew aboard the International Space Station (ISS). Although this is the sort of view we on Earth only wish we could see in person, the ISS crew must consider this a mundane experience. Due to the high-velocity orbit of their habitat, the crew encounter this event 16 times in a day.

The station's solar arrays produce more power than required for the onboard systems and experiments. When the Sun's rays bathe the Space Station, about 60 per cent of the electricity generated is used to charge the station's batteries to ensure that it is powered when the spacecraft is not in the Sun.

© NASA

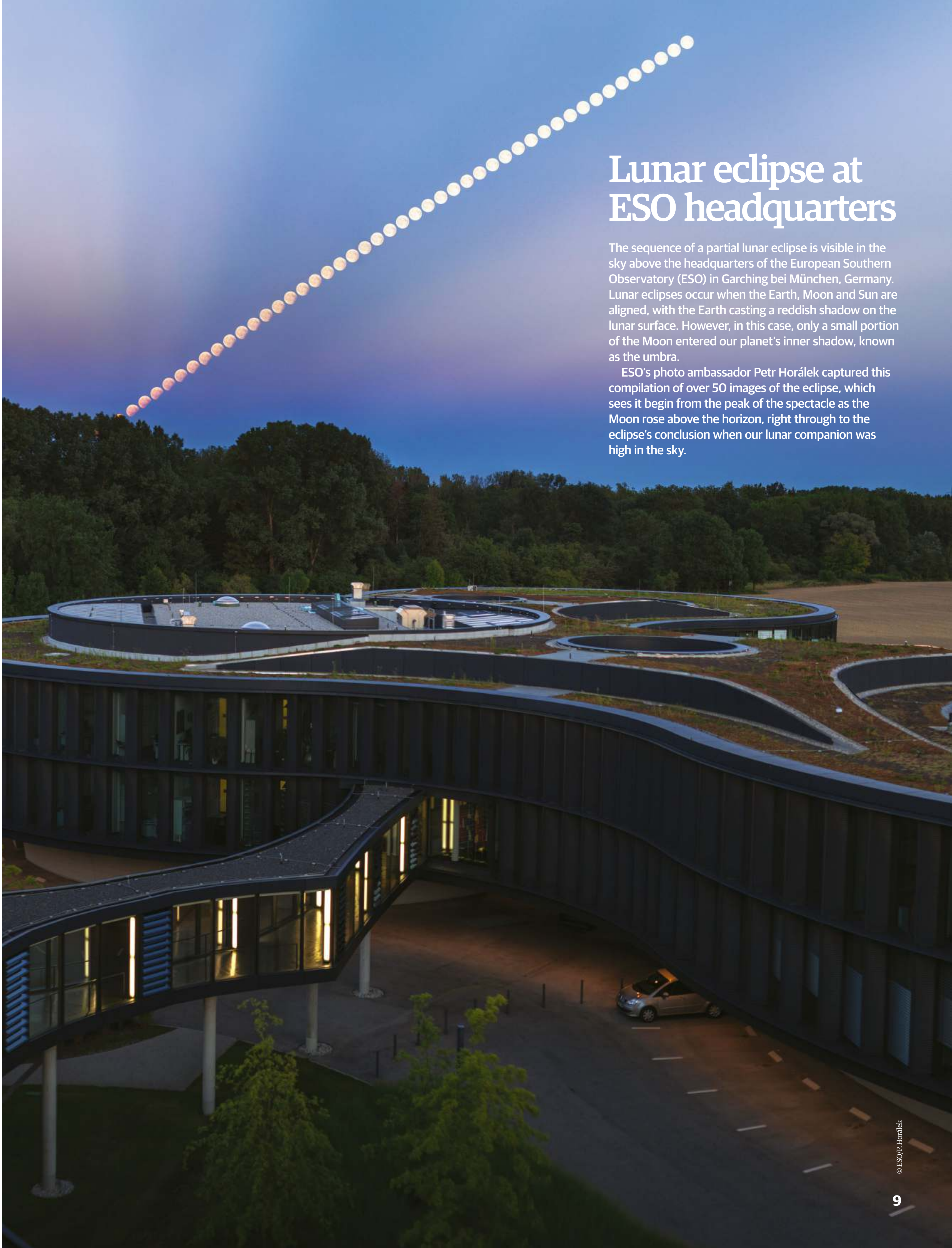


## Large telescope improvement

How do you make a great telescope even better? Well for the European Southern Observatory (ESO)'s Very Large Telescope (VLT), a new Adaptive Optics Facility (AOF) was added. This revolutionary equipment includes artificial lasers, deformable active mirrors and multiple wavefront sensors, which assist the telescope in combating Earth's tempestuous atmosphere that would otherwise cause fuzzy images.

The inset image shows the distinct improvement in the quality of the VLT's snap of planetary nebula NGC 6369. The shot on the left reveals the VLT's natural 'sight', while the opposing shot provides ground-layer correction to provide a much sharper and clearer spectacle.

© Roland Bacon; ESO/P. Weilbacher (AIP)

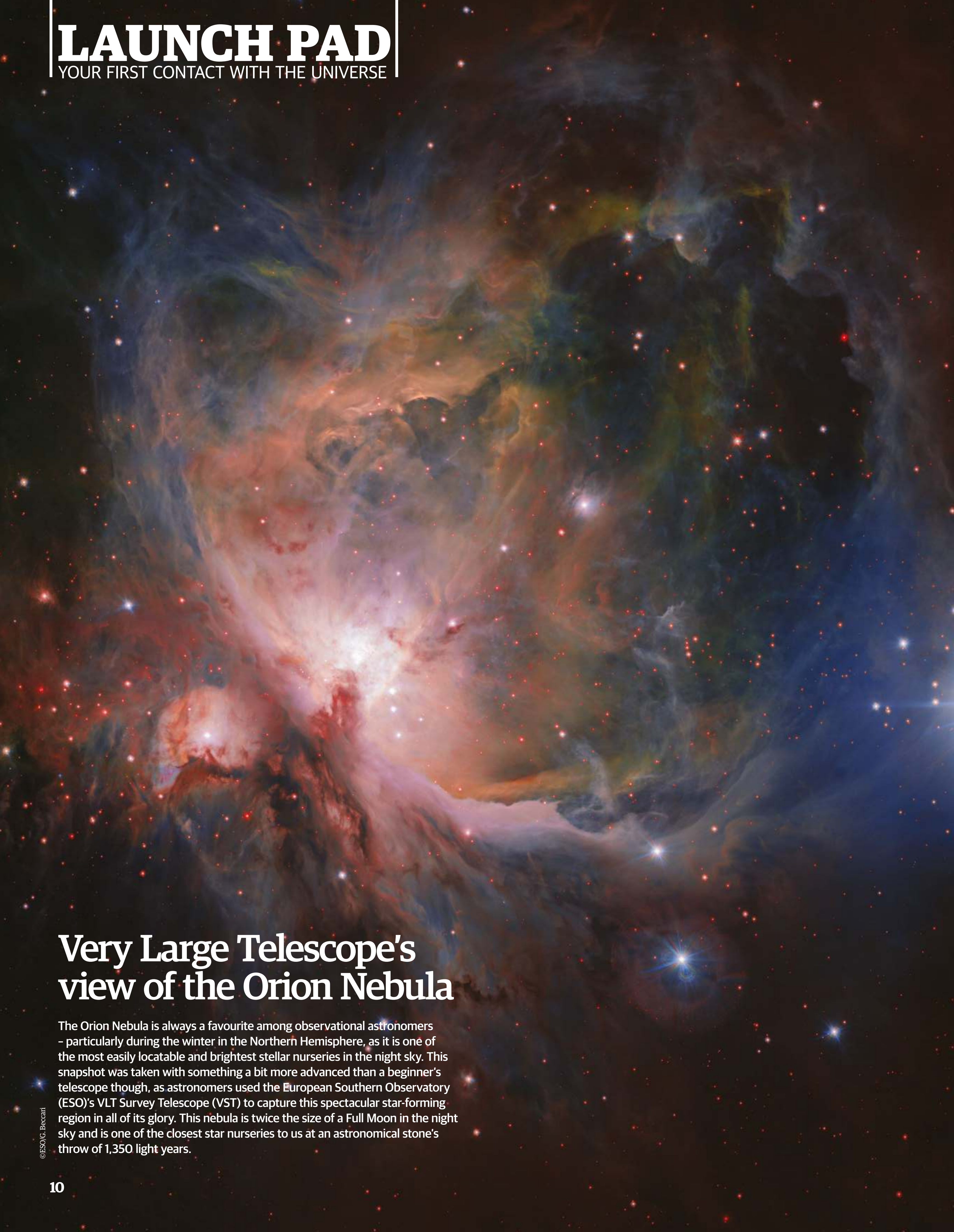


# Lunar eclipse at ESO headquarters

The sequence of a partial lunar eclipse is visible in the sky above the headquarters of the European Southern Observatory (ESO) in Garching bei München, Germany. Lunar eclipses occur when the Earth, Moon and Sun are aligned, with the Earth casting a reddish shadow on the lunar surface. However, in this case, only a small portion of the Moon entered our planet's inner shadow, known as the umbra.

ESO's photo ambassador Petr Horálek captured this compilation of over 50 images of the eclipse, which sees it begin from the peak of the spectacle as the Moon rose above the horizon, right through to the eclipse's conclusion when our lunar companion was high in the sky.

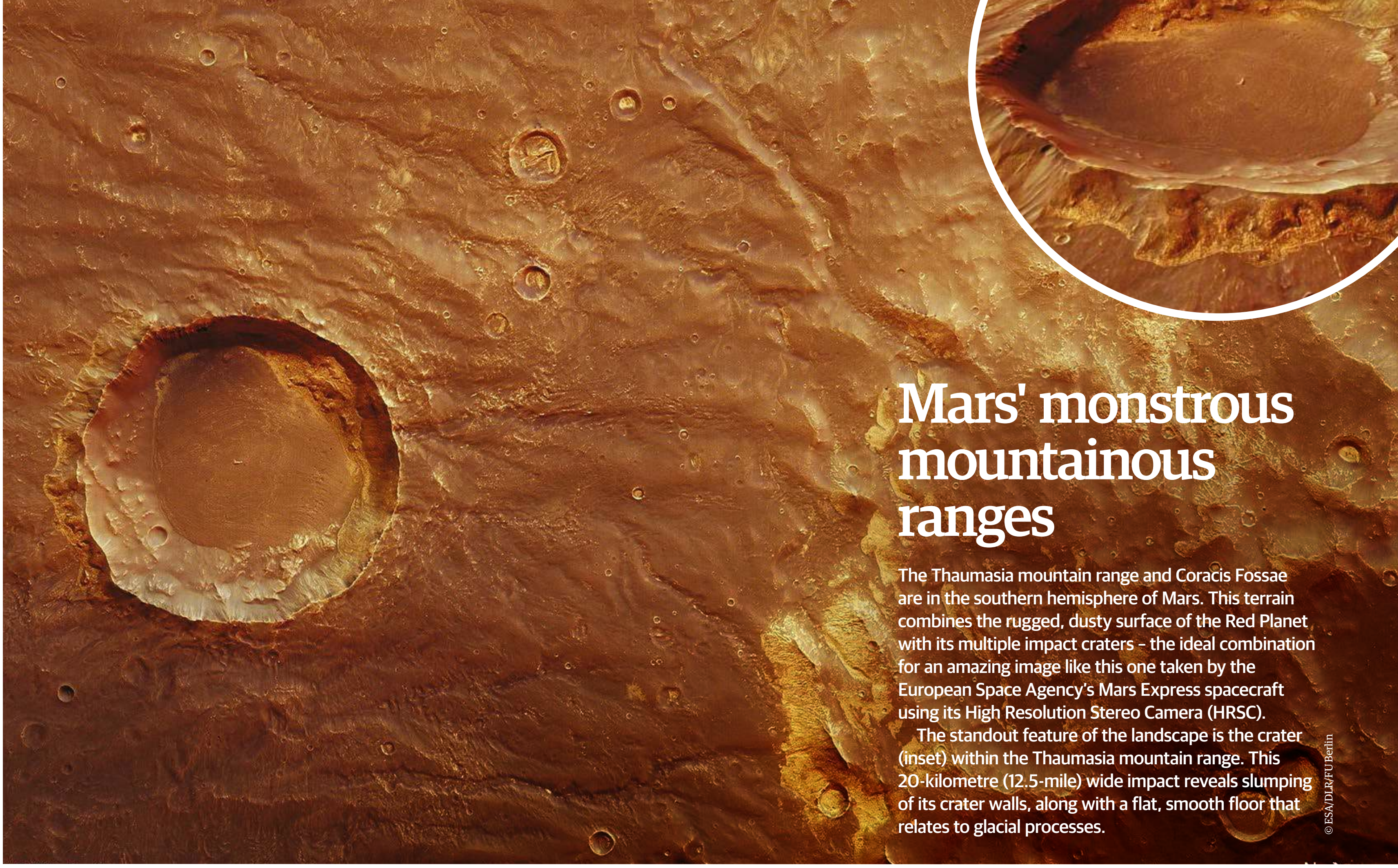
© ESO/P. Horálek



# Very Large Telescope's view of the Orion Nebula

The Orion Nebula is always a favourite among observational astronomers – particularly during the winter in the Northern Hemisphere, as it is one of the most easily locatable and brightest stellar nurseries in the night sky. This snapshot was taken with something a bit more advanced than a beginner's telescope though, as astronomers used the European Southern Observatory (ESO)'s VLT Survey Telescope (VST) to capture this spectacular star-forming region in all of its glory. This nebula is twice the size of a Full Moon in the night sky and is one of the closest star nurseries to us at an astronomical stone's throw of 1,350 light years.

©ESO/G. Beccari

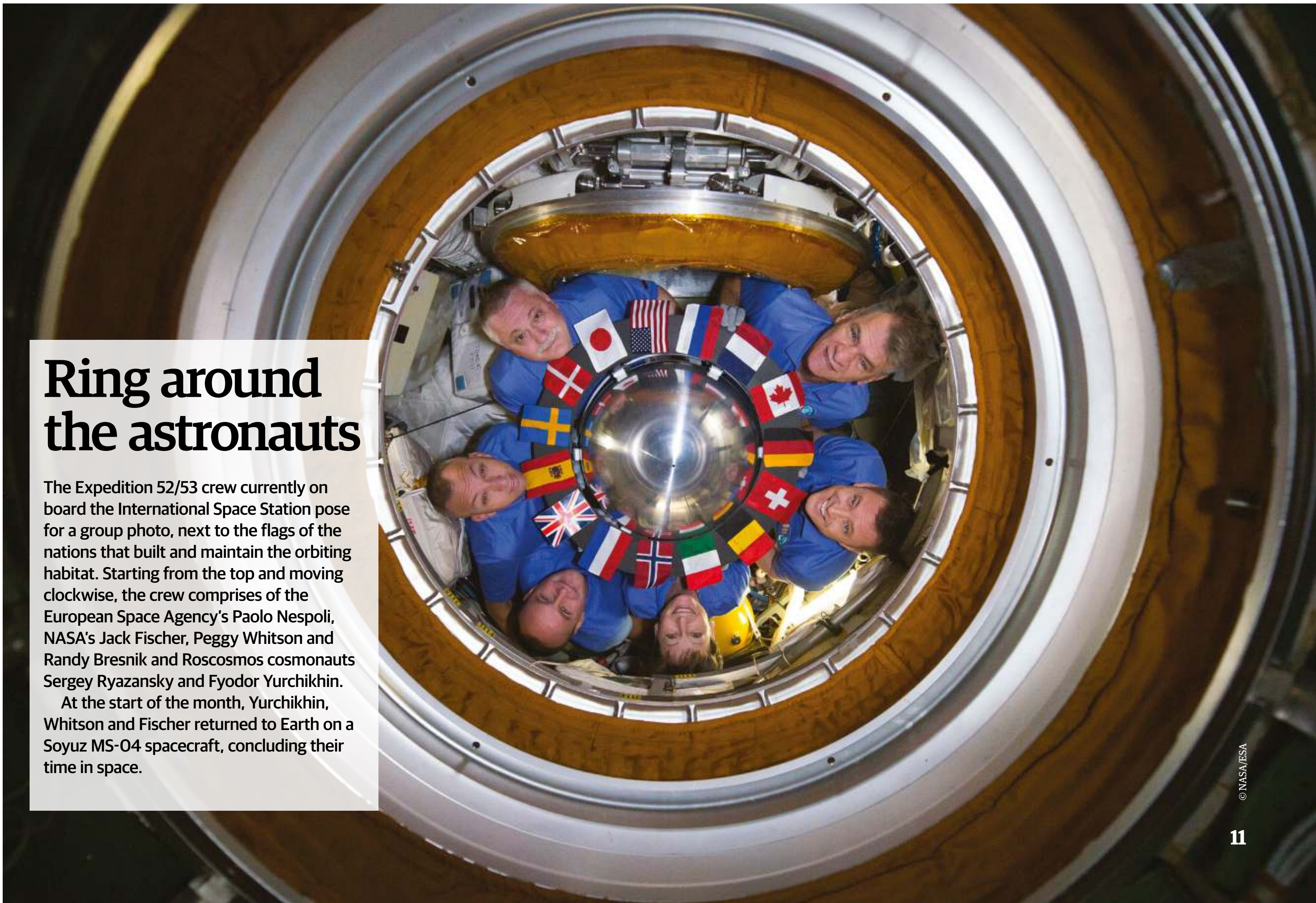


# Mars' monstrous mountainous ranges

The Thaumasia mountain range and Coracis Fossae are in the southern hemisphere of Mars. This terrain combines the rugged, dusty surface of the Red Planet with its multiple impact craters – the ideal combination for an amazing image like this one taken by the European Space Agency's Mars Express spacecraft using its High Resolution Stereo Camera (HRSC).

The standout feature of the landscape is the crater (inset) within the Thaumasia mountain range. This 20-kilometre (12.5-mile) wide impact reveals slumping of its crater walls, along with a flat, smooth floor that relates to glacial processes.

© ESA/DLR/FU Berlin



# Ring around the astronauts

The Expedition 52/53 crew currently on board the International Space Station pose for a group photo, next to the flags of the nations that built and maintain the orbiting habitat. Starting from the top and moving clockwise, the crew comprises of the European Space Agency's Paolo Nespoli, NASA's Jack Fischer, Peggy Whitson and Randy Bresnik and Roscosmos cosmonauts Sergey Ryazansky and Fyodor Yurchikhin.

At the start of the month, Yurchikhin, Whitson and Fischer returned to Earth on a Soyuz MS-04 spacecraft, concluding their time in space.

© NASA/ESA

# TRAPPIST-1's planets likely to be like Mars

## The planetary system may be twice as old as our Solar System, and its potentially life-bearing worlds may actually be like the Red Planet

Scientists studying TRAPPIST-1 - the system comprised of a red dwarf star orbited by seven planets similar in size to Earth - claim they are a step closer to determining its age. Having made several observations of the star system along with other red dwarfs, the astronomers have concluded it is at least 5.4 billion years old. Indeed, they say it could even be 9.8 billion years of age, which would make it twice as old as our own Solar System. The findings will help scientists determine whether life could survive on the planets.

TRAPPIST-1, which is 39 light years away, is being heralded as a great find. In February, scientists discovered there were seven exoplanets around the star, three of which are said to be in the habitable zone. Knowing its age, though, allows astronomers to come up with more robust theories. Stars that are young emit high-energy radiation all too frequently, which negatively affects the surface of a planet. Older stars, meanwhile, have exposed planets to stellar radiation for too long a time, making neither ideal for life as we know it.

Even so, this most recent dating still leaves many questions open with regards to the planet's habitability. Adam Burgasser, an astronomer at the University of California, San Diego, and Eric Mamajek, deputy program scientist for NASA's Exoplanet Exploration Program, say the closeness of the planets to the star means large amounts of water and atmosphere may have been boiled off over the years. If so, it would make it the most likely candidate planets more akin to Mars than Earth, although the lower densities of the TRAPPIST-1 planets compared to our own raises the potential of there being large reservoirs of volatile molecules such as water.

These could produce thick atmospheres that would act to shield the surface of the planets from harmful radiation, yet there is a potential of the planets overheating. As you can imagine, it means scientists are still far from knowing for sure, which is why future observations using NASA's Hubble Space Telescope and the upcoming James Web Space Telescope will seek to cast fresh light on the issue. They may well reveal the presence and nature of an atmosphere on the planets.

"If there is life on these planets, I would speculate that it has to be hardy life, because it has to be able to survive some potentially dire scenarios for billions of years," says Burgasser, who measured the age by looking at the number of flares emitted, the chemical composition of the atmosphere and how fast the star moved in orbit around the Milky Way, with slower stars tending to be younger.

> "If there is life on these planets, I would speculate that it has to be hardy life"

An artist's impression of how the TRAPPIST-1 system may look if an image was taken from near TRAPPIST-1f

©NASA/JPL-Caltech

Antares appears white in this false-colour infrared image taken by the Wide-field Infrared Survey Explorer (WISE) telescope

©Judy Schmidt

# Behaviour of supergiant star locked down

## A study has sought to find out why Antares is expelling so much matter as it gets close to the end of its life

What happens when a red giant nears the end of its life has been the subject of a fascinating new study in Chile. Keiichi Ohnaka, a researcher at Catholic University of the North, has been studying the red supergiant star Antares, to gain a more solid grasp of its late-life behaviour.

Using a pioneering technique, he was able to see how the gas in the star's outer atmosphere was moving. He did so with the intention of better understanding how it expels large amounts of matter off its surface as it gets closer to becoming a supernova - something that would help scientists learn more about the eventual fate of our own Sun.

Antares is the fifteenth-brightest star in the night sky. It is classified as a red supergiant, meaning it is in the late stage of its evolution when it develops a complex atmosphere of multiple components. The star is understood to be between 15 and 18 times as massive as the Sun and has around 883 times its radius. To study it, Ohnaka used the European Space Observatory's Very Large Telescope Interferometer to observe the motion of the carbon monoxide gas in the star's atmosphere. In doing so, he was able to measure the velocity of gas at various positions.

"The two-dimensional velocity field map obtained from our near-infrared spectro-interferometric imaging reveals vigorous upwelling and downdrafting motions of several huge gas clumps at velocities ranging from about -20 to +20 kilometres per second in the atmosphere," Ohnaka tells **All About Space**.

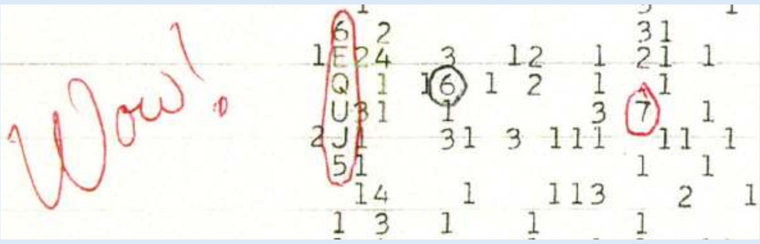
# 'Wow!' signal boosts search for extraterrestrials

## SETI marks the 40th birthday of the signal, while astronomers keep their fingers crossed for a second coming

The Search for Extraterrestrial Intelligence Institute (SETI Institute) has celebrated the passing of four decades since volunteer astronaut Jerry Ehman spotted a conspicuous signal that lasted for around a minute. In a bid to catch a second glimpse of it, the organisation has enlisted the help of amateur astronomer Robert Gray.

Gray is the author of the best-selling book, *The Elusive Wow: Searching for Extraterrestrial Intelligence*, and he is known for his work as an independent researcher. SETI Institute senior astronaut Seth Shostak, who wished the signal a happy birthday on 15 August this year, says the data analyst is using the Alien Telescope Array to collect 100 hours of new data from the direction of the Wow! Signal.The observations, he continued, are still in progress. "They have the potential to end the mystery, and tell us that, 40 years ago, someone was trying to get in touch," Shostak adds. But while others have sought to explain the phenomenon - so-called because Ehman wrote Wow! on the printout - no theory has yet gained suitable widespread approval.

"A recent paper by researchers in Florida suggested that natural emissions from comets might have accounted for this famous detection, although that seems very unlikely," Shostak wrote in his blog post. The not-for-profit SETI Institute has been looking for evidence for life in the universe by looking for a signature of its technology since it was incorporated in 1984.



©Big Ear Radio Observatory, NAAPO

## Space News in brief

### Brown dwarfs have Neptune cloud

Atmospheric bands of clouds have been seen drifting across the skies of brown dwarfs for the first time. Observers using NASA's Spitzer Telescope say it explains the variations in brightness and the large-scale movement of particles in the atmosphere of these 'failed stars'.

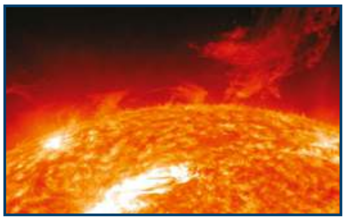
©NASA/JPL-Caltech

### Secret of jellyfish galaxies revealed

Scientists have discovered that active supermassive black holes are at the centre of some so-called jellyfish galaxies - and that the long tendrils of such structures are feeding them. Astrophysicist Bianca Poggianti says the black holes are eating up hot gas, making ideal feeding grounds.

### Sun's core rotates faster than surface

The core of our Sun has been found to rotate roughly four-times faster than its surface. Roger Ulrich, a University of California astronomer, used data from the SOHO satellite to calculate the extent sound waves travelling from within the Sun to the surface are distorted by gravity.



© NASA

### CubeSat to unlock Venus mystery

NASA will send a CubeSat mission to Venus to discover why it looks like a striped ball. Called the CubeSat UV Experiment, it will determine the chemistry, composition and radiative transfer of the atmosphere using ultraviolet-sensitive instruments and a light-gathering mirror.

### Stay up to date...

**www.spaceanswers.com**
Fascinating space facts, videos & more

**Twitter** @spaceanswers
**Facebook** /AllAboutSpaceMagazine

# LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

The Explorers Program concentrates on creative ideas to unravel the mysteries of the universe

## NASA shortlists six 'Explorer' missions

### Scientists are being asked to state their case in the hope of being selected in the near future

Six potential space missions have been earmarked by NASA, as the space agency vows to continue unravelling the mysteries of the universe. The astrophysics proposals aim to look at the emissions of gamma-rays and X-rays from both galaxy clusters and neutron star systems. They are also seeking to study infrared emissions from galaxies in the early universe, along with the atmospheres of exoplanets.

The planned missions are split into two categories: Medium-Class Explorer and Missions of Opportunity. Those in the former are Arcus, which will study stars, galaxies and clusters of galaxies using hi-res X-ray spectroscopy to characterise the interactions between these and the gas that surrounds them, FINESSE, which will investigate the processes governing planet formation and global climate and SPEHEREx, which will perform an all-sky near-infrared spectral survey to probe the origins of the universe

Those in the Missions of Opportunity category are COSI-X, which will be a balloon-borne, wide-field-of-view telescope designed to survey the gamma-ray sky, ISS-TAO, which will be a wide-field X-ray transient detector on the ISS to observe numerous X-ray transients and CASE, which will provide additional detectors to the Atmospheric Remote-Sensing Infrared Exoplanet mission.

One mission will be chosen from each category depending on how well they state their case. Those advancing the Medium-Class Explorer missions have received $2 million (£1.5 million) with $500,000 (£384,000) going to the Missions of Opportunity proposals. They have been given nine months to come up with a mission concept study.

## It may snow on the Red Planet tonight

### Violent snowstorms are understood to batter the fourth rock from the Sun in the middle of the night when the atmosphere becomes cold enough

A simulation of the weather conditions on the Red Planet suggests there can be intense snowstorms during the night. The surprising find for a planet that is generally perceived as being dry and dusty has been made by a team of French and American astronomers.

They say the global temperature drops at night, leading water-ice particles to form clouds. When they become unstable, they release water-ice precipitation to the surface of the planet in bursts that can last for several hours. Many of the flakes fail to reach the ground, leading to only a slight dusting of the white stuff. The study backs observations made by NASA's Phoenix lander nine years ago.

A NASA spacecraft noted snow falling on the Red Planet in the form of frozen carbon dioxide in 2012

© NASA

Back then, Phoenix noticed wispy structures which appeared similar to virga streaks on Earth - that is cloud precipitation that doesn't reach the ground. It was followed in 2012 by what seemed to be a cloud of carbon dioxide snowflakes over the southern pole, as noted by NASA's Mars Reconnaissance Orbiter. The storms are more intense than anyone thought, given Mars' thin atmosphere.

"In our simulations, convective snowstorms occur only during the Martian night, and result from atmospheric instability due to radiative cooling of water-ice cloud particles," says lead scientist Aymeric Spiga, a tenured lecturer at the Université Pierre et Marie Curie. "This triggers strong convective plumes within and below clouds, with fast snow precipitation resulting from the vigorous descending currents." The findings are based on computer models of the Martian atmosphere.

## Most-distant massive galaxy provides view of early universe

A galaxy, which existed just 760 million years after the Big Bang, has been spotted by an international team of astronomers. Known as SPT0311-58, it is the most-distant massive, dusty, star-forming galaxy to be discovered and it is helping scientists work out how the early universe appeared and evolved.

Its luminosity and size means scientists could find clues as to how the neutral atoms of early galaxies came to be reionised.

"The mere fact that such massive galaxies already existed when the universe was still so young puts strong constraints on our understanding of galaxy mass buildup," Maria Strandret and Alex Weiss of the Max Planck Institute for Radio Astronomy explains. "Furthermore the dust needs to form in a very short time, which gives additional insights on the dust production from the first stellar population in the universe."

© NASA, ESA, Harald Ebeling, Jean-Paul Kneib

# FEED YOUR MIND

www.howitworksdaily.com

DID LIFE COME FROM COMETS?
FREE POSTERS!
HOW IT WORKS
HOW WE'LL CURE CANCER
THE GROUNDBREAKING RESEARCH AND INNOVATIVE THERAPIES HELPING US FIGHT BACK
DOGS WITH JOBS
MEET THE CLEVER CANINES WITH CAREERS
THE SPACE SHUTTLE
EXTREME OFF-ROADERS
OVER 900 FACTS AND ANSWERS INSIDE
JAGUAR I-PACE
HISTORIC HEISTS
RASPBERRY PI
+ SPACE PHOTOS KATHERINE JOHNSON SILICON VALLEY
DA VINCI'S MARVELLOUS MACHINES
LAST DAYS OF THE DINOS
RECORD-BREAKING WEATHER
+RUBIK'S CUBES TYRES
CAR WASHES
AIRPORT SECURITY
100th ISSUE
10 MARVELS OF THE ANCIENT WORLD

# HOW IT WORKS™

ON SALE NOW

Available from all good newsagents and supermarkets

- HOW WE'LL CURE CANCER • DOGS WITH JOBS • EXTREME OFF-ROADERS

**SCIENCE UP CLOSE**

**INSIDE GADGETS**

**COOLEST TECH**

**ILLUSTRATIONS**

**AMAZING FACTS**

## BUY YOUR ISSUE TODAY

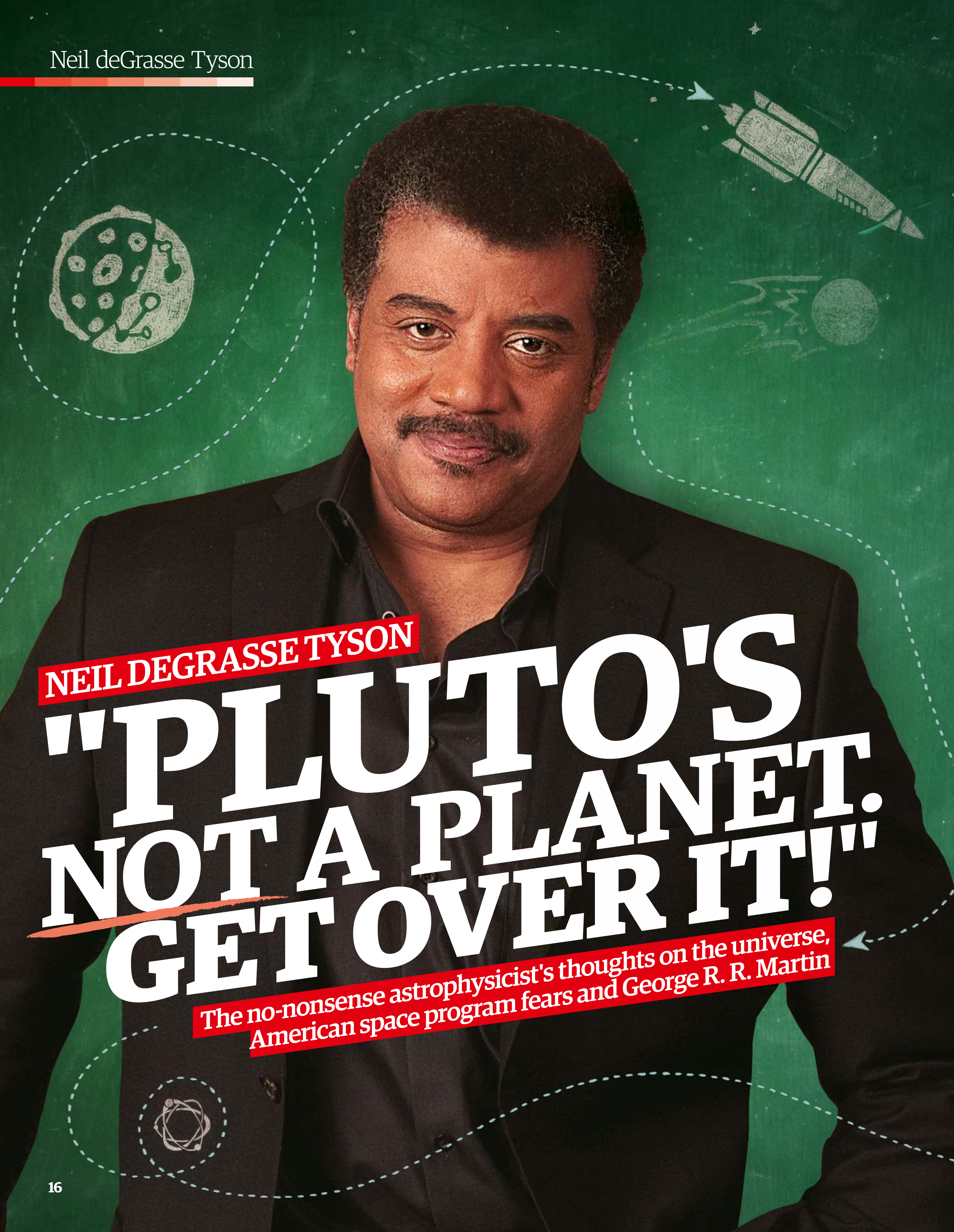
Print edition available at www.myfavouritemagazines.co.uk

Digital edition available at www.greatdigitalmags.com

Available on the following platforms

Print Tablet Phone Desktop

facebook.com/howitworks twitter.com/@howitworksmag



**NEIL DEGRASSE TYSON**

# "PLUTO'S NOT A PLANET. GET OVER IT!"

The no-nonsense astrophysicist's thoughts on the universe, American space program fears and George R. R. Martin

# Neil's notes on the universe

**Pluto should remain a dwarf planet**

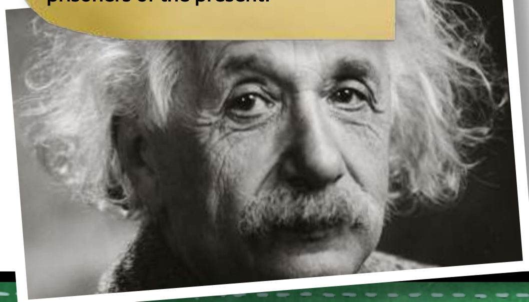
Tyson says anyone upset at Pluto's demotion to dwarf planet status in 2006 should get over it. "Pluto is happier now. It's one of the largest of the dwarf planets in the Kuiper Belt," he says.

**We are living in a simulation**

It may not be Tyson's own theory, but he has no argument against it. "If you have tremendous computing power," he states, "you could simulate every possible thing that could occur."

**Life elsewhere in the universe**

"We are not likely alone in the universe if you look at how common the ingredients of life are," Tyson says. "Hydrogen, oxygen, nitrogen, carbon, we're made of this stuff."



**Time is a dimension**

Tyson says Einstein's discovery of general relativity means time is a fluid concept. "Time is relative, so time can be stretched, for me relative to you." As for time travel, we are "prisoners of the present."

**Dark matter may not be matter**

Since scientists know little about dark matter, Tyson says it should be renamed. "Fred," he jokes, before explaining that the stuff, which can only be observed indirectly, may not be matter at all.

It is becoming ever harder to ignore Neil deGrasse Tyson - not that you'd ever want to, of course. As one of the world's most high-profile astrophysicists, he has authored no fewer than 14 best-selling books about the universe, contributed to and written many research papers and appeared on numerous television and radio shows.

He is one of the reasons why so many people have become interested in space. His long-lived career has not only earned him scores of awards and 18 honorary doctorates, but also some personal affection along the way. Tyson was named the 'sexiest astrophysicist alive' by *People* magazine in 2000 - something that crops up time and time again. He also once professed to have been "a nerd who could kick your butt" at school.

Perhaps ironic then that one of his most successful jaunts of recent years has been his weekly audio podcast, *StarTalk*, where his face and body have been firmly hidden behind a microphone - although the show did make a transition to television courtesy of National Geographic. In recent weeks, he has been on a high following a successful campaign to get his first video game off the ground. *Space Odyssey* raised more than the $314,159 goal that had been set on crowdfunding website Kickstarter. The game will allow players to set out on real science-based missions to explore space and colonise planets.

It is rather interesting that Tyson would get involved in such a venture, though. The current director of the American Museum of Natural History's Hayden Planetarium has often spoken about the idea of our real-life universe being a simulation. He then tells **All About Space** that he felt it would be "really cool if we were some alien simulation, maybe someone's PhD thesis experiment." He wondered aloud if the aliens would become restless and create disruptions to their otherwise peaceful, tranquil world. Anyone who has ever played *The Sims* would instantly get what he was saying, with some people playing only to create chaos for their simulations.

> "It is easy for me to imagine that everything in our lives is just a creation of some other entity for their entertainment" **Neil deGrasse Tyson**

"All I can say is that I do not have a good argument against the hypothesis," he tells us. He has said the likelihood that we exist as software is "very high", explaining that there could so easily be a being whose intelligence surpasses our own. "If that's the case," he says, "it is easy for me to imagine that everything in our lives is just a creation of some other entity for their entertainment."

He draws our attention on this subject to Nick Bostrom, a philosopher from the University of Oxford. Bostrom's paper, *Are You Living In a Computer Simulation* started the whole hypothesis. He argued that one of the following three propositions was true: that the human species would likely go extinct before reaching the point at which they could produce ultra-real environments; that 'posthuman' civilisations were extremely unlikely to run a significant number of simulations of their evolutionary history, and that we are almost certainly living in a computer simulation.

In Bostrom's mind, we don't have strong enough evidence to rule out any of these possibilities. In Tyson's mind, the same is true. "It's not my opinion," he tells us, "and in any case it's not about my opinion. It's simply an idea advanced by others for which I have no rebuttal." One of Tyson's colleagues, Max Tegmark, who is a professor of astrophysics at the Massachusetts Institute of Technology, has likened this to a game of Nintendo's Mario.

© NASA/JHUAPL/SwRI; ESA; ESO

What if all of our space simulations are just part of a bigger simulation of a creator who wants to explore its game world?

“If we are a simulation of some super intelligent alien species, is that indistinguishable from people's concept of God?” **Neil deGrasse Tyson**

“Let's say you are in the game,” Tyson explains. “You start taking measurements and you say, 'if I jump, I jump this high, and the others characters don't jump as high as I do'. So you start setting up laws of motion that apply inside the game. Eventually you might figure out all the laws of motion, and that is your world. But is that anything different to what we're doing with our branches of science? We're trying to figure out the laws of nature. Well, where do those laws come from? It's still a little bit of a mystery.”

He is certainly very philosophical about the whole thing. “Religious people would say God made the laws, but if you're more prone to secular accounts of things, you might ask: are these coming about naturally, or by hand by someone who has created our world for their own entertainment?” He continues, “And then you get deeply philosophical and say if we are a simulation of some super intelligent alien species, is that indistinguishable from people's concept of God? That's another interesting path to have a debate over a beer at a bar on; something to start arguing about because everyone is going to have an opinion, no matter how much or little research they have done on it.”

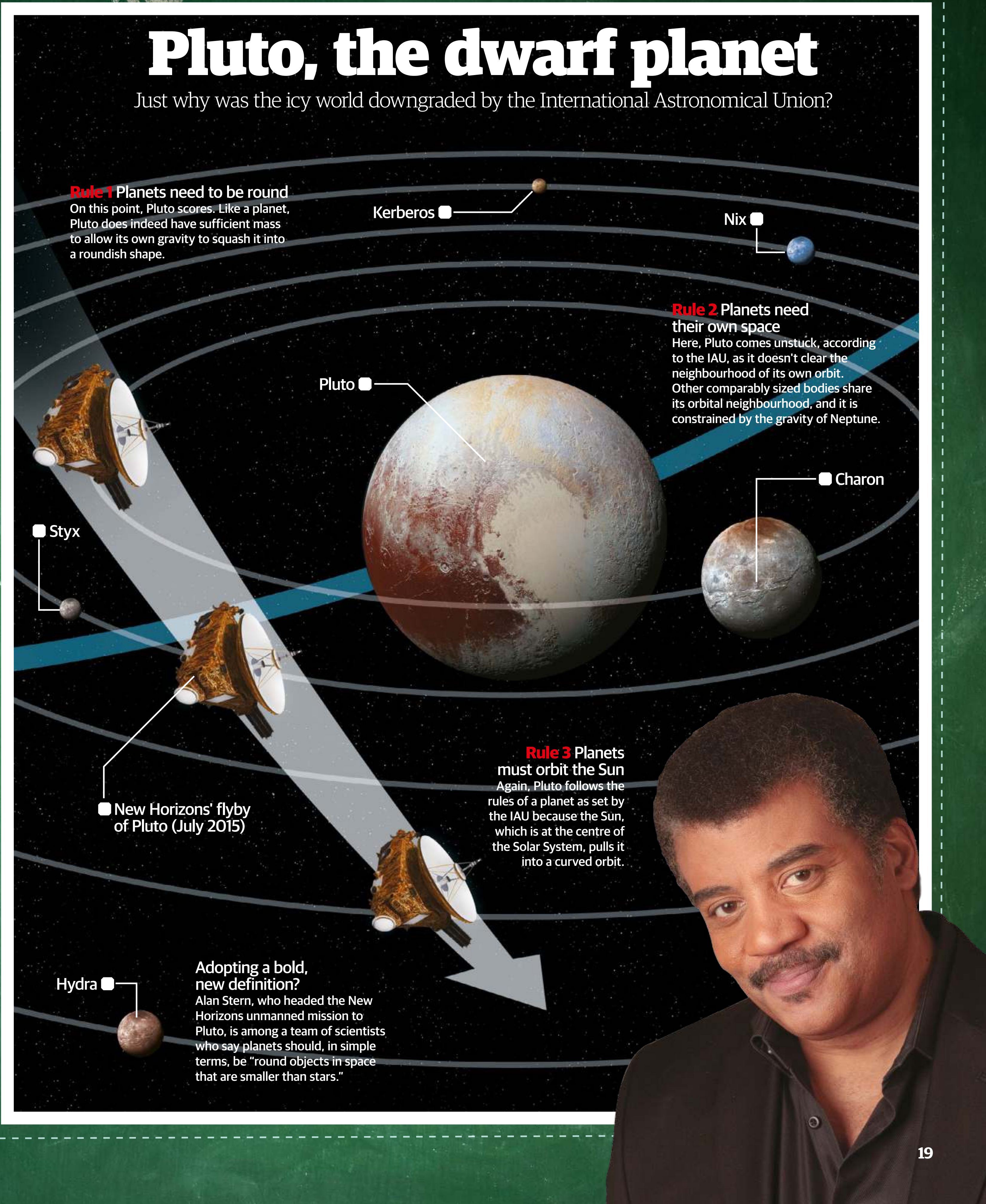
The question of whether or not Tyson actually believes in God himself is one which has been asked in the past. Talk show host Chelsea Handler put that query to him, to which the astrophysicist answered: “Every description of God that I've heard holds God to be all-powerful and all-good. But then I look around and I see a tsunami that killed a quarter of a million people in Indonesia, and an earthquake, which killed a quarter of a million in Haiti. I see tornadoes, disease and childhood leukemia. I see all of this and I say that I do not see evidence of both of those being true simultaneously. If there is a God, then God is either not all-powerful, or not all-good.”

Tyson is frequently asked to lend his opinion on all sorts of subject matter. As a regular on the sofa of many a talk show, he has often spoke of his personal and scientific thoughts, and his considered, slowly

We may have made it to space, but we still have a whole lot to learn

# Pluto, the dwarf planet

Just why was the icy world downgraded by the International Astronomical Union?



**Rule 1** Planets need to be round

On this point, Pluto scores. Like a planet, Pluto does indeed have sufficient mass to allow its own gravity to squash it into a roundish shape.

**Rule 2** Planets need their own space

Here, Pluto comes unstuck, according to the IAU, as it doesn't clear the neighbourhood of its own orbit. Other comparably sized bodies share its orbital neighbourhood, and it is constrained by the gravity of Neptune.

**Rule 3** Planets must orbit the Sun

Again, Pluto follows the rules of a planet as set by the IAU because the Sun, which is at the centre of the Solar System, pulls it into a curved orbit.

**Adopting a bold, new definition?**

Alan Stern, who headed the New Horizons unmanned mission to Pluto, is among a team of scientists who say planets should, in simple terms, be "round objects in space that are smaller than stars."

© NASA/JHUAPL/SwRI; Maciej Rebisz

worded responses usually get a great reaction. In March of this year, he appeared on *The Late Show with Stephen Colbert*, where he discussed whether Pluto should be considered a planet rather a dwarf planet. "They should just get over it," he said bluntly with a smile, nodding to those at NASA pushing for an upgraded definition (their numbers include Alan Stern who headed the New Horizons mission to Pluto). "Pluto had it coming from the beginning," he continued. "Its orbit crosses that of another planet, and that's no kind of behaviour for a planet."

The fact Pluto can't clear the neighbourhood around its orbit led the International Astronomical Union to downgrade the body in 2006 – "stay in your lane; stay in your lane", Tyson laughed, reacting to Pluto's crossing of Neptune's path. When pressed on the matter of definition by **All About Space**, though, he was quite clear: "I don't actually care what people call it," he told us, "so in short you've got the wrong guy [if you want someone to talk against Pluto being a dwarf planet] even though, on the surface, I might seem like the right guy."

He explained his stance as essentially following the guidelines set more than a decade ago. "I am cast by many as a person who thinks Pluto should not be a planet," he told us, "but in fact, in my home institution, we do not say it's not a planet. We simply group it with the Kuiper Belt." He pointed to his book on the subject, *The Pluto Files: The Rise and Fall of America's Favourite Planet*, as well as a PBS video he hosted. "At no time did I say it is not a planet [in the book or video] until after the IAU declared it a dwarf planet," he explains. "Then, any such statement from my mouth was citing their decision."

In his mind, the matter of Pluto is settled, leaving him room to argue about other things, be they *Star Wars* ("BB-8, a smooth-rolling metal spherical ball, would have skidded uncontrollably on sand," he explains), or the pronunciation of Uranus. When he appeared on *Celebrity Family Feud*, he got into a jovial argument with host Steve Harvey. "Yup," he later tweeted, "@IamSteveHarvey blew a gasket after I told him pronouncing Uranus as 'Your-Anus' was okay for 8-yr-olds, but not adults."

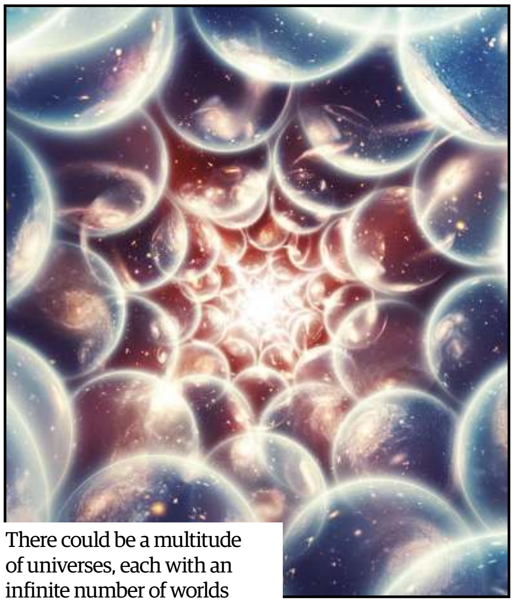
Tyson, though, is a science educator, and he likes to get things right. He explains his subject matter in a clear, balanced and well-thought-out manner, and he is not afraid to call out those he feels are failing to do the same. "The rise of flat-Earthers in society provides some of the best evidence for the failure of our educational system," he says. But then he feels a sense of responsibility. "I'm an educator and I feel a certain duty to educate the public," he says. Indeed, his latest book, *Astrophysics for People in a Hurry*, is helping him achieve that aim as he looks at black holes, anti-matter, warped space and more.

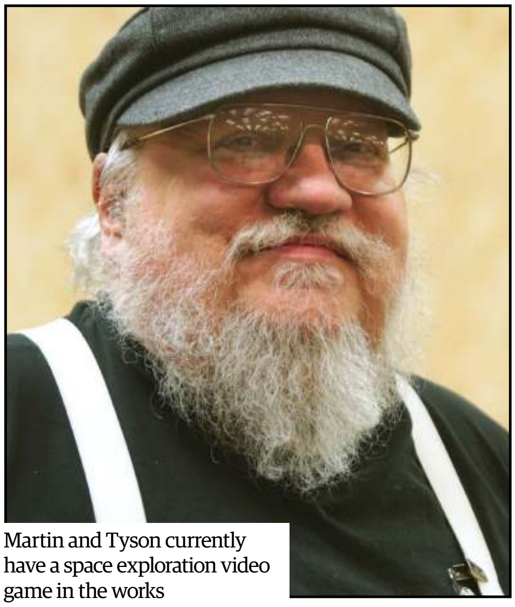
By giving people a grounding in space, he hopes they'll go on to explore its more complex

> "There are compelling arguments out there for why there might be a multiverse, and they are grounded in physics" **Neil deGrasse Tyson**

Could our entire world be fabricated by an intelligent being? How would we know if it was?

Tyson's work explores the universe accessibly and for people without a scientific background


There could be a multitude of universes, each with an infinite number of worlds


Martin and Tyson currently have a space exploration video game in the works

Tyson is always quick to call out scientific inaccuracies in film and television

theories, whether it's the idea of a multiverse or the holographic principle. "The hologram hypothesis is intriguing," he says. "You come up with it when you have an event horizon around a black hole, and I'm intrigued by that; this idea that we are a record of something playing out in another way inside of an event horizon." He also says "there are compelling arguments out there for why there might be a multiverse, and they are grounded in physics and sometimes quantum physics. The idea of multiple universes is a high-concept idea and people have a bit of armchair philosopher in them."

Tyson has pointed out before that there are sound theoretical reasons to think we live in a multiverse. He says the tenets of quantum physics - the physics of the small - have been tested and found to be true. The same goes for general relativity - the physics of the large. He says that they don't work with one another as they stand today, so he argues that you have to take the universe back to the Big Bang, when the entire universe was small. "Now you take the shotgun wedding - quantum physics and general relativity," he says. "In that shotgun wedding, if you follow through with all the predictions quantum physics gives you, it allows multiple bubbles to form - one of which is our universe." What's more, he says the multiverse may not be alone and could be one of many.

It's a shame, then, that a multiverse is not going to feature in Tyson's upcoming video game, which he's working on with *Game of Thrones* creator George R. R. Martin, that allows users to explore space and colonise planets. "I like that they're creating a world that needs to be self-consistent," Tyson explains. "Winter is coming, so what does that mean? I'm thinking about it as an astrophysicist: what kind of planet would that be? What kind of orbit would it

© Gage Skidmore; Tobias Roetsch;

"In science, if you don't do it, somebody else will. Whereas in art, if Beethoven didn't compose the 'Ninth Symphony,' no one else before or after is going to compose the 'Ninth Symphony' that he composed; no one else is going to paint 'Starry Night' by Vincent van Gogh."

"We are part of this universe; we are in this universe, but perhaps more important than both of those facts, is that the universe is in us."

# What Neil said...

"The universe is under no obligation to make sense to you."

"The good thing about science is that it's true whether or not you believe in it."

"We account for one-sixth of the forces of gravity we see in the universe. There are no known objects accounting for most of the effective gravity in the universe. Something is making stuff move that is not anything we have ever touched."

"When I look up in the universe, I know I'm small but I'm also big. I'm big because I'm connected to the universe and the universe is connected to me."

"Perhaps we've never been visited by aliens because they have looked upon Earth and decided there's no sign of intelligent life."

Advancements in technology are making Mars colonisation look possible as part of our future

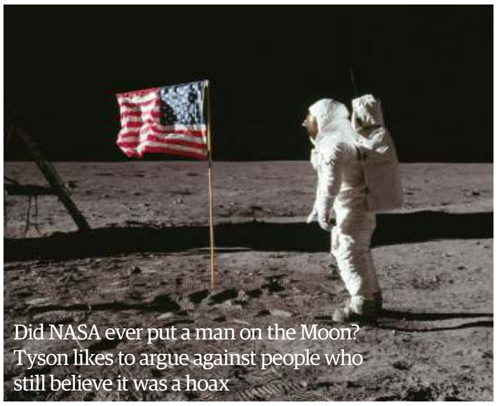
> “How remarkable it is for some humans to be so struck by our advances in science and technology that they are in denial” **Neil deGrasse Tyson**

have? What kind of star is it? It's clearly not Earth, although they're all humans – except for the dragons!"

In real life, though, he has said that he would want future attempts to colonise Mars to involve two-way trips, drawing attention to the explorers of the past who had always given others the chance to try their discovery and come back if it didn't work out. “That's different from saying 'here's a spaceship that is only designed to go one way and, by the way, when you get there, there's no air or water,'” he argues.

As for those who persist in claiming the moon landings were a conspiracy, he says, “how remarkable it is for some humans among us to be so struck by our advances in science and technology that they are in denial that it is real. What a compliment that is.” He talks of the more-than-sufficient amount of fuel on board the spacecraft that took the astronauts and the lander to the Moon, and questions: “Where do people think they were going?” He also says the rest of us need to move on from trying to prove humans landed on the moon and just accept it as fact. It's typical of his no-nonsense approach.

Indeed, Tyson says we need to focus on the future, funding NASA sufficiently and showing the value for money American citizens get from the space program (“right now, NASA's annual budget is half a penny on your tax dollar,” he told the United States Senate Science Committee in 2012). But he fears the US is turning away from science. “The consequence of that is that you breed a generation of people who do not know what science is nor how and why it works,” he says. “Innovations in science and technology are the basis of tomorrow's economy.”



Did NASA ever put a man on the Moon? Tyson likes to argue against people who still believe it was a hoax

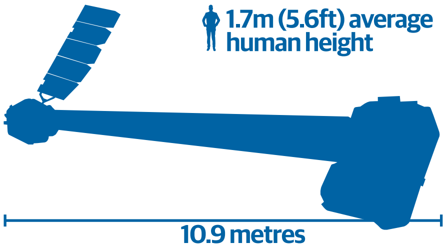
© Stocktrek Images, Inc. / Alamy Stock Photo

# Nuclear Spectroscopic Telescope Array (NuSTAR)

Recently celebrating five years in space, the spacecraft is the first, and only, orbiting telescope to focus high-energy X-rays into sharp images

## THE SPECS

**Launch:** 13 June 2012
**Rocket:** Pegasus XL
**Target:** Low Earth equatorial orbit
**Operators:** NASA
**Estimated cost:** $170 million
**Time in space:** 5 years
**Orbit height:**
604km (375 miles)



When NuSTAR launched in 2012, it became the first orbiting observatory that could focus light in the highly energetic X-ray section of the electromagnetic spectrum. This gives scientists the chance to examine a branch of astronomy that had been restricted by the atmosphere, technologies and instruments. By being able to observe the shortest wavelengths emitted from the universe's most powerful sources, NuSTAR is still trying to answer the mysteries about black holes, supernovae and even our nearest star, the Sun.

NuSTAR's launch had an array of setbacks; in 2006 the mission was actually cancelled due to cuts in NASA's budget. Fortunately, in 2007, the mission was restarted and set for launch in August 2011, but was yet again delayed until June 2012. NuSTAR was launched from the Kwajalein Atoll in the Marshall Islands, using a Pegasus XL rocket attached to the "Stargazer" L-1011 aircraft. On 13 June 2012, the Stargazer aircraft, courtesy of Orbital Sciences, reached an altitude of approximately 13 kilometres (8 miles) before releasing the Pegasus rocket. Pegasus metaphorically 'picked up the baton' and reached the low Earth orbit of 604 kilometres (375 miles). NuSTAR has orbited Earth at this altitude ever since, travelling round our equator.

This process was much easier than launching Hubble back in 1990. Not only has our understanding of space exploration improved, but also the NuSTAR payload was drastically less massive. NuSTAR has much less equipment, the bulk of which are its 'twin' X-ray optics and detector modules. Its sole purpose is to study the highly energetic light from the universe, and nothing else. The instruments onboard NuSTAR include the ten-metre mast, which was successfully deployed days after the launch, separating the focussing optics and the detector modules.

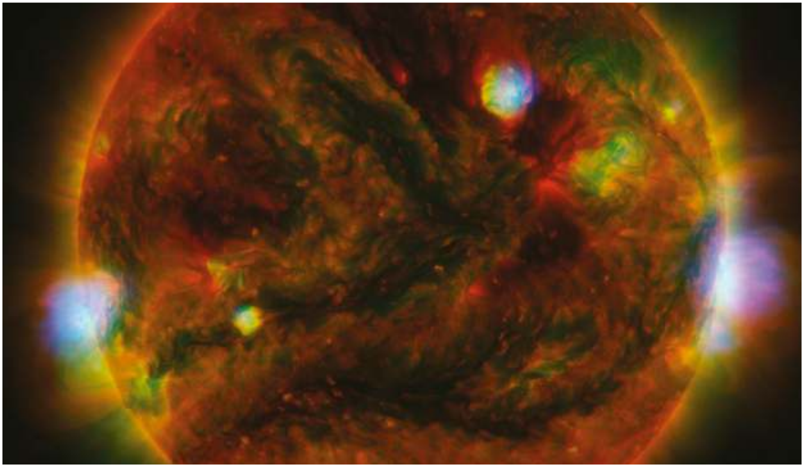
The optics are, by far, the most impressive and complicated aspect of this space telescope. They don't act like normal telescope mirrors: with visible light, normal mirrors or lenses reflect the light into the detector. The problem with X-ray light is that it's too energetic, and gets absorbed by the regular mirrors or lenses. This requires what is known as

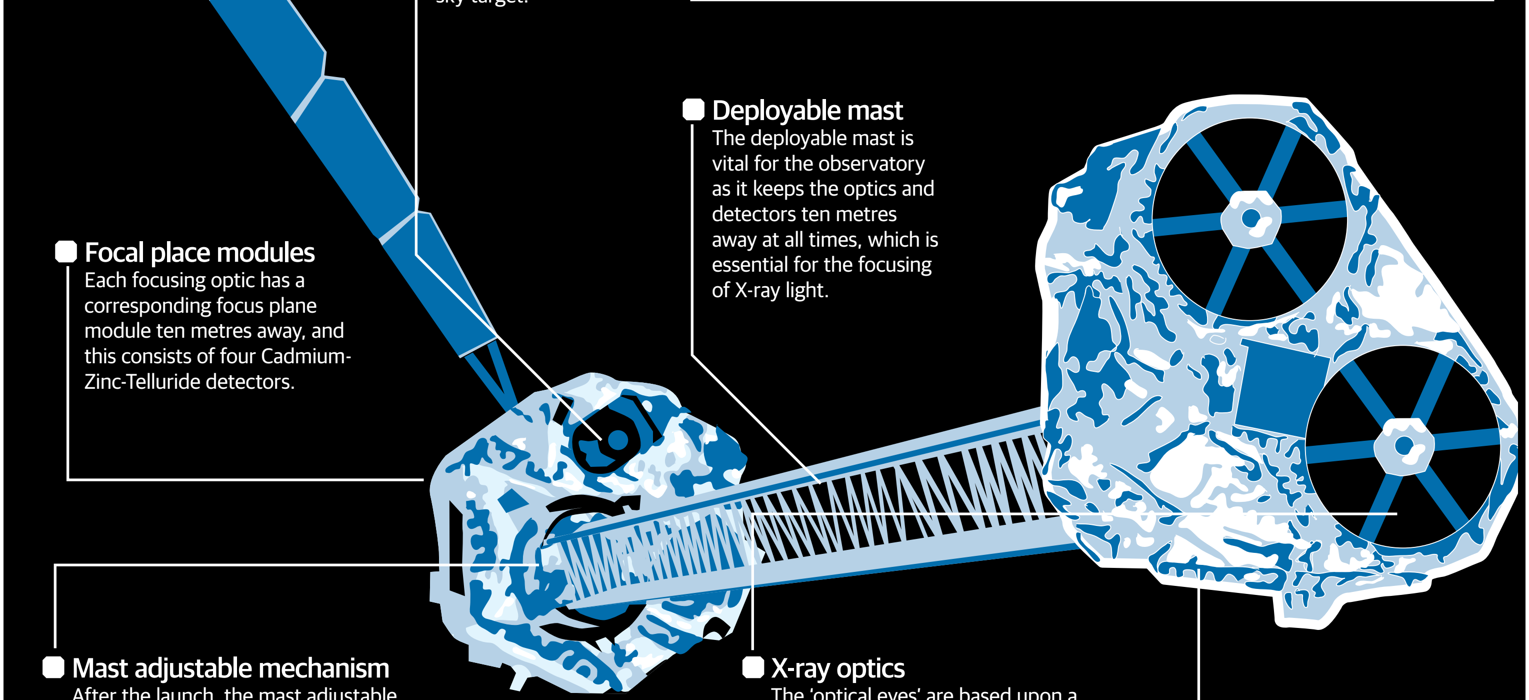
Principal investigator of NuSTAR, Fiona Harrison

**NuSTAR nestled in the nose cone of the Pegasus XL rocket**

# Anatomy of NuSTAR

The equipment aboard NuSTAR was designed purely to watch the most powerful events in the universe and uncover their secrets





**Solar array**
There is only one solar panel aboard NuSTAR, which makes it all the more valuable. This solar panel creates 750 Watts of power that runs the observatory.

**Star tracker**
The star tracker is connected to the spacecraft's metrology system to ensure the observatory is properly aligned with its deep sky target.

**Deployable mast**
The deployable mast is vital for the observatory as it keeps the optics and detectors ten metres away at all times, which is essential for the focusing of X-ray light.

**Focal place modules**
Each focusing optic has a corresponding focus plane module ten metres away, and this consists of four Cadmium-Zinc-Telluride detectors.

**Mast adjustable mechanism**
After the launch, the mast adjustable mechanism was used to deploy the ten-metre mast. This happens immediately after the solar panel deployment.

**X-ray optics**
The 'optical eyes' are based upon a 'Wolter-I' approximation, consisting of 133 concentric mirror shells, designed to focus the high-energy X-rays into the detectors.

**Metrology lasers**
The metrology laser system of NuSTAR constantly measures the motion of the mast, to make sure the detectors and optics are aligned.

> "NuSTAR has provided fundamental results for our understanding of black holes"

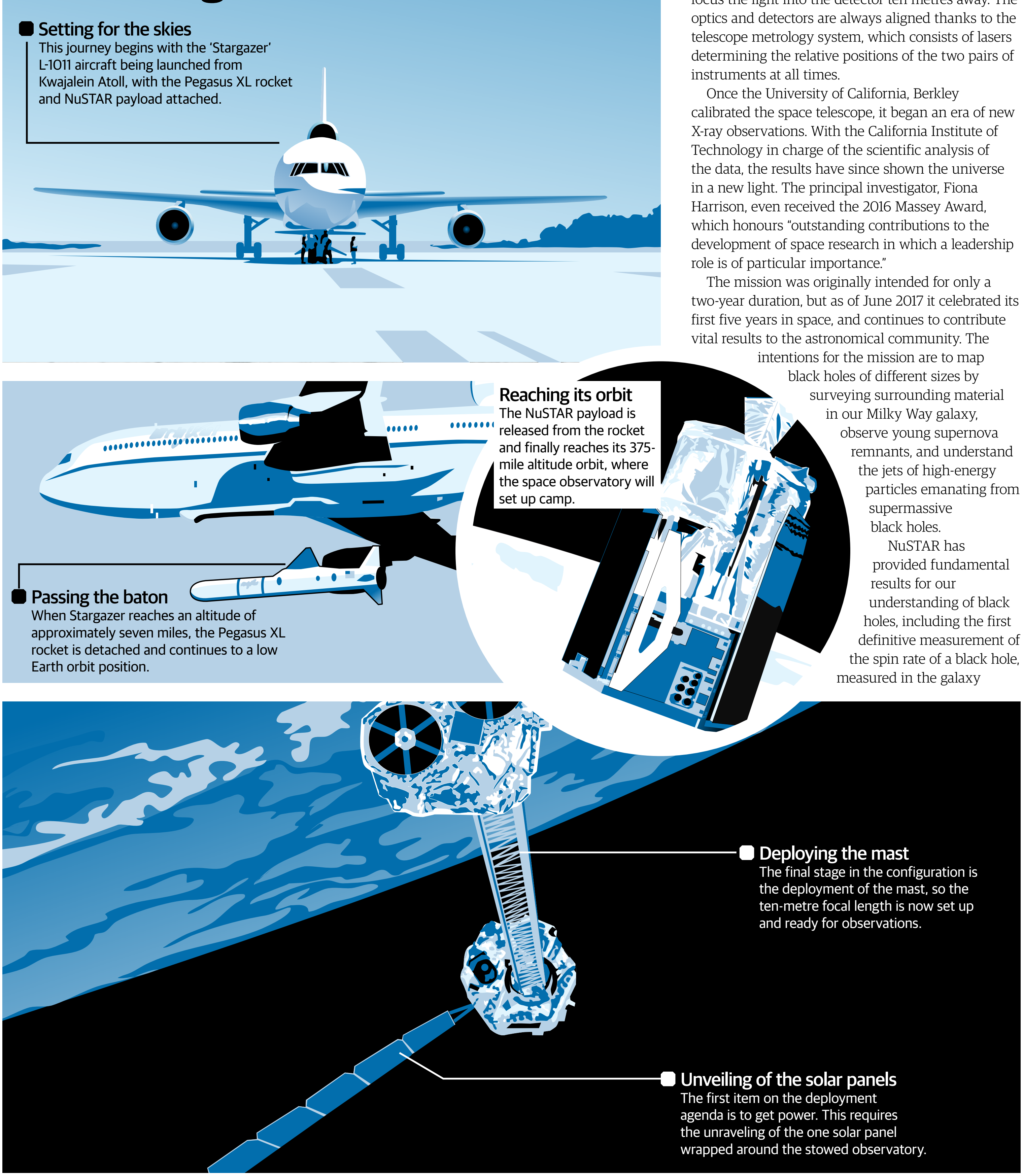
© Adrian Mann; ASA/JPL-Caltech/GSFC/JAXA

a 'Wolter telescope' approximation. In the case of NuSTAR, it's 133 concentric mirror shells designed to focus the light into the detector ten metres away. The optics and detectors are always aligned thanks to the telescope metrology system, which consists of lasers determining the relative positions of the two pairs of instruments at all times.

Once the University of California, Berkley calibrated the space telescope, it began an era of new X-ray observations. With the California Institute of Technology in charge of the scientific analysis of the data, the results have since shown the universe in a new light. The principal investigator, Fiona Harrison, even received the 2016 Massey Award, which honours "outstanding contributions to the development of space research in which a leadership role is of particular importance."

The mission was originally intended for only a two-year duration, but as of June 2017 it celebrated its first five years in space, and continues to contribute vital results to the astronomical community. The intentions for the mission are to map black holes of different sizes by surveying surrounding material in our Milky Way galaxy, observe young supernova remnants, and understand the jets of high-energy particles emanating from supermassive black holes. NuSTAR has provided fundamental results for our understanding of black holes, including the first definitive measurement of the spin rate of a black hole, measured in the galaxy

# How to... get NuSTAR into orbit



**Setting for the skies**
This journey begins with the 'Stargazer' L-1011 aircraft being launched from Kwajalein Atoll, with the Pegasus XL rocket and NuSTAR payload attached.

**Passing the baton**
When Stargazer reaches an altitude of approximately seven miles, the Pegasus XL rocket is detached and continues to a low Earth orbit position.

**Reaching its orbit**
The NuSTAR payload is released from the rocket and finally reaches its 375-mile altitude orbit, where the space observatory will set up camp.

**Deploying the mast**
The final stage in the configuration is the deployment of the mast, so the ten-metre focal length is now set up and ready for observations.

**Unveiling of the solar panels**
The first item on the deployment agenda is to get power. This requires the unraveling of the one solar panel wrapped around the stowed observatory.

© Adrian Mann

NGC 1365. These results showed that X-ray energies aren't being distorted by surrounding clouds, but instead distorted by the sheer gravity of the supermassive black hole.

When NuSTAR turned its sights to supernova remnants, it not only produced a fantastic image of Cassiopeia A (Cas A), it also mapped the radioactive material expelled by the massive explosion. By mapping this material, scientists were able to deduce that the uneven distribution of titanium among the remnants suggests that the material literally sloshed around, causing the final shock wave that expelled the outer layers.

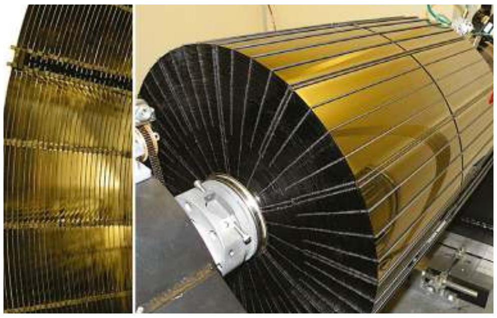
The NuSTAR team decided to push the space telescope to its limits, and pointed it towards the Sun. "People thought we were crazy at first to point such a sensitive observatory at the Sun, and potentially ruin it," says Harrison. "But now, by studying the Sun with much greater sensitivity in high-energy X-rays, we are making important contributions to the field of solar physics."

Surpassing both the sensitivity of the Chandra X-ray observatory and XMM-Newton telescope, it is hard to envision a space telescope that could dethrone NuSTAR. With more space observatories designed to answer more cosmological questions, such as Laser Interferometer Space Antenna (LISA) and the Euclid spacecraft, NuSTAR will remain the leading telescope with regards to high-energy X-ray emission. With no set date for the decommission of NuSTAR, it will continue in its quest to understand the most powerful events and objects in the universe.

**TOP TECH**

## Wolter-I optics: how do they focus the energetic X-rays?

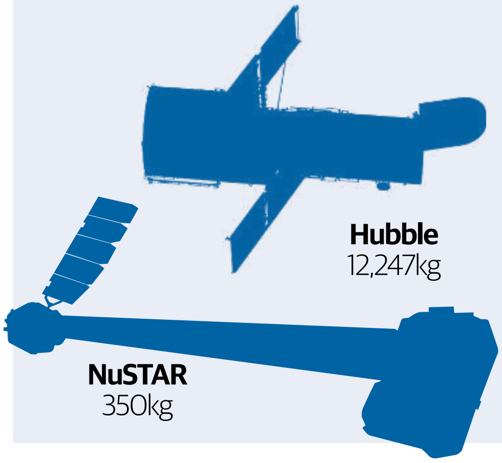
How do you reflect energetic light that is normally absorbed by regular mirrors or lenses? The answer is found in NuSTAR's two optic units, which are a testament to modern day engineering and physics. These units are able to focus X-ray light by having it reflect off the mirrors at almost parallel angles. The X-ray optic mirrors are more complex than what amateur astronomers are used to: these mirrors consist of 133 concentric ultra-thin glass shells, no wider then the thickness of a fingernail. Along with its reflective coating for each shell, these optical units are the reason why NuSTAR can observe higher energy light than Chandra or XMM-Newton.



## Head to head

### Hubble vs NuSTAR

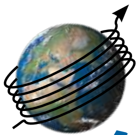
When you compare the properties of the telescopes, NuSTAR pales in comparison to the Hubble Space Telescope. However, these two telescopes are observing light on different ends of the electromagnetic spectrum. Hubble is 35-times the mass of NuSTAR, which weighs in at 350 kilograms, but Hubble has many more instruments - including four spectrographs - which add considerably to the mass. As for size, when NuSTAR has the mast deployed, it reaches 10.9 by 1.2 metres, which isn't much smaller than Hubble's 13.2 by 4.2 metres.



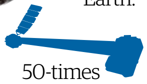
## Vital statistics

**10.9** metres in length. = That's longer than two large family cars.

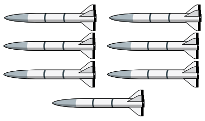
**80keV** The highest frequency NuSTAR can observe. = 63-times the frequency of visible light.



**750 million miles** Distance travelled since launch in 2012. = That's roughly 30,000 orbits of Earth.



**350Kg** The mass of NuSTAR. = 50-times lighter than the Pegasus rocket that launched it.



**17,000 mph** The speed it travels around the equator. = Roughly 70-times the speed of a torpedo.

**HOW TO…**

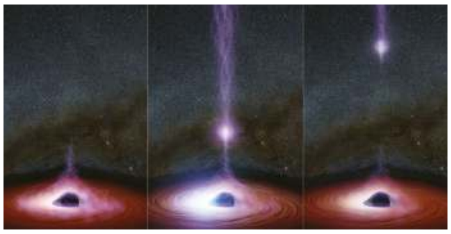
## Observe a black hole

### 1 Observing what you can't see

Because light can't escape a black hole, and they are normally enshrouded by gas and dust, we can't directly see what is happening. We are reliant upon the highly energetic material around the black hole to infer any behaviour.

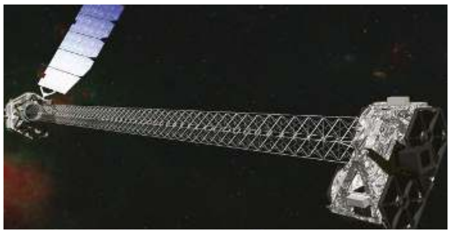
### 2 Releasing the X-ray light

The material that surrounds the black hole becomes hot, dense and energetic. Jets and flares occur as a way to release energy. The energy released is in the form of high-energy X-rays, which are only visible by the NuSTAR observatory.



### 3 Collecting and focusing the light

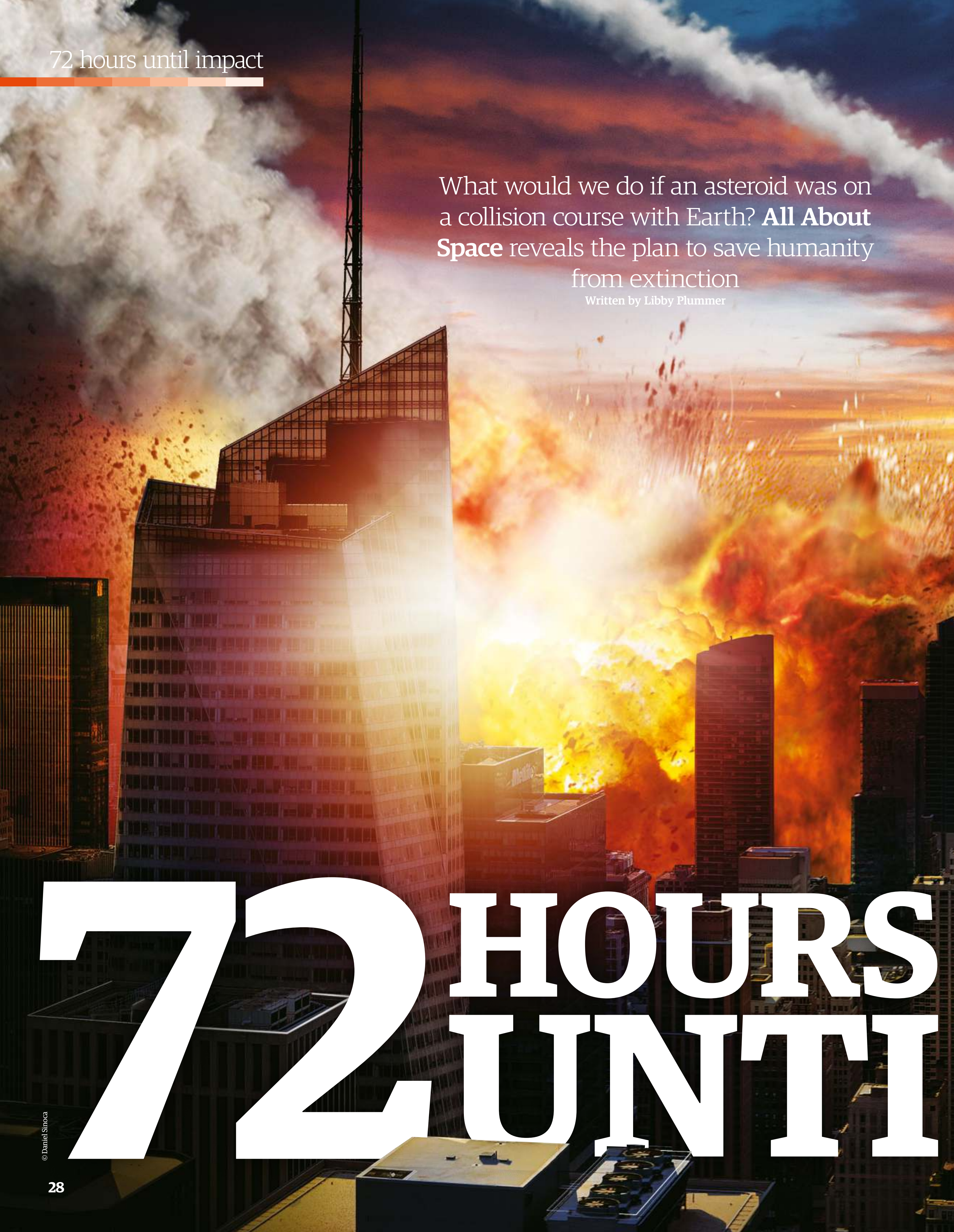
These X-rays travel across the universe, thousands upon thousands of light years, before they reach NuSTAR. The twin optics then focus the light, using its Wolter-I approximation configuration, towards the focal place modules.



### 4 Sending it to Earth

Observations are transmitted back to Earth in images that are ten-times sharper than previous X-ray observatories. The results from the black holes are analysed by a team of astronomers, based at the California Institute of Technology.

© NASA/JPL-Caltech/GSFC

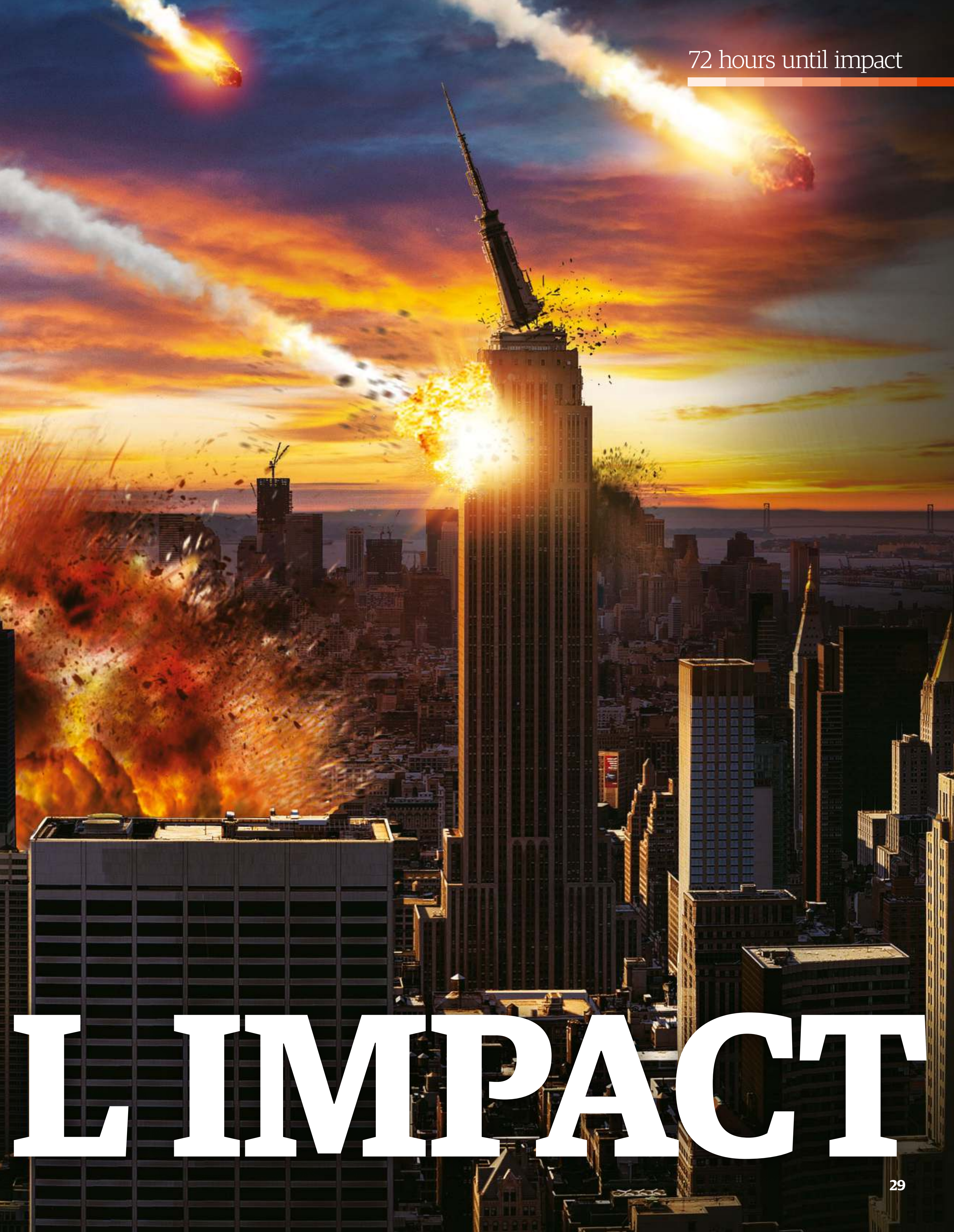


# 72 HOURS UNTI

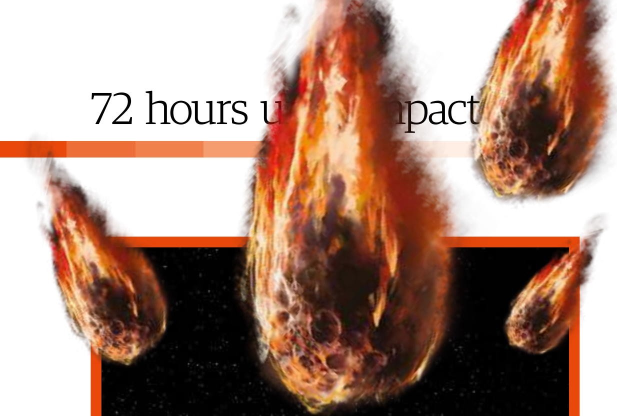
What would we do if an asteroid was on a collision course with Earth? **All About Space** reveals the plan to save humanity from extinction

Written by Libby Plummer

© Daniel Sinoca



# L IMPACT



## Potential risks to planet Earth

NASA's JPL keeps a constantly updated tally of potentially hazardous asteroids using its Sentry System

### (410777) 2009 FD

**Detected by:** Spacewatch
**Likely size:** 160m
**When it could hit:** 2185-2198
One of thousands of Apollo asteroids – the largest group of near-Earth asteroids – this binary asteroid could hit Earth between 2185 and 2198.

### 101955 Bennu

**Detected by:** Lincoln Near-Earth Asteroid Research (LINEAR)
**Likely size:** 490m
**When it could hit:** 2175-2199
A C-type asteroid – one that's made up largely of carbon – Bennu is the target of NASA's OSIRIS-REx asteroid sample-gathering mission.

### (29075) 1950 DA

**Detected by:** Carl A. Wirtanen, Lick Observatory
**Likely size:** 1.3km
**When it could hit:** 2880
This massive asteroid has the highest known probability of impacting Earth and would cause major devastation due to its size.

### 99942 Apophis

**Detected by:** Roy Tucker, David Tholen and Fabrizio Bernardi, Kitt Peak National Observatory (KPNO)
**Likely size:** 370m
**When it could hit:** 2060-2105
Previously expected to impact as early as 2029, this asteroid set a record for the highest rating on the Torino Scale, which rates impact hazard.

A civilisation-destroying asteroid may sound like the stuff of science fiction, but the threat is very real.

These rocky fragments range in size from mere metres to hundreds of kilometres across, and while most orbit the Sun in a belt between Mars and Jupiter, the gravitational pull of planets can sometimes alter their path. If an asteroid, or a fragment of one – known as a meteoroid – makes it to the Earth's atmosphere, it usually burns up as a meteor or shooing star. However, some explode in a massive fireball, and some make it down to the Earth's surface as meteorites.

In 2013, a 10,000-ton meteor, measuring 18 metres across, hurtled into the Earth's atmosphere at 67,000 kilometres (41,600 miles) per hour before exploding 23.3 kilometres (14.4 miles) above the Russian city of Chelyabinsk. More than 1,000 people were injured as a result of the fireball, mainly by shattered glass caused by the shockwave, though luckily nobody was killed. The surprise explosion released more than 30-times the energy than that from the Hiroshima atomic bomb. To put that in perspective, the massive meteor strike that is thought to have triggered the extinction of the dinosaurs measured around 10 kilometres across and released around a billion-times the energy of an atomic bomb. Before impact, the asteroid was completely undetected because it was "too small for the survey telescopes, and came at us out of the Sun", according to NASA. The potentially catastrophic incident highlighted just how important it is to monitor Near Earth Objects (NEOs) – comets and asteroids that have been nudged into Earth's neighbourhood.

For gaining support to develop a better surveillance network for NEOs, "Chelyabinsk helped a lot," Rüdiger Jehn, who co-manages ESA's Space Situational Awareness (SSA) and NEO team, told **All About Space**. Following the strike, the European Space Agency secured vital funds to build its new 'fly-eye' telescope, which is expected to begin operations in 2019. Taking inspiration from insects which can look in multiple directions at the same time, the bug-eyed telescope splits the image into 16 sub-images to expand the field of view – up to a massive 45 square degrees.

"This is a big improvement," says Jehn, continuing, "this enables us to scan the entire sky in one night, so if something is coming, we should see it. We hope that we will be able to spot NEOs measuring 40 metres three weeks before they approach Earth".

The 40-metre mark is significant because this is the approximate size of the 1908 Tunguska meteoroid which flattened 2,000 square kilometres of remote Siberian forest in the most harmful asteroid-related incident in recent history. While it's thought that this sort of size asteroid only threatens the Earth every 300 years or so, smaller 10-metre asteroids, as seen over Chelyabinsk, are more regular. The fly-eye telescope is a major step forward in safeguarding the planet from NEOs, and ESA also has guidelines in place should the worst happen.

"We have a detailed information plan," says Jehn. "If we spotted an NEO three weeks away, we would not inform the public straight away as we would not want to cause a panic. The data is very sensitive and we have to be careful how we handle it. We would compare readings with NASA and tell rescue specialists and government agencies everything we know and what kind of damage to expect, and then it would be their job to decide on the right plan of action".

> "The likelihood of an asteroid impact is really low, but the consequences can be unimaginable" **Clemens Rumpf**

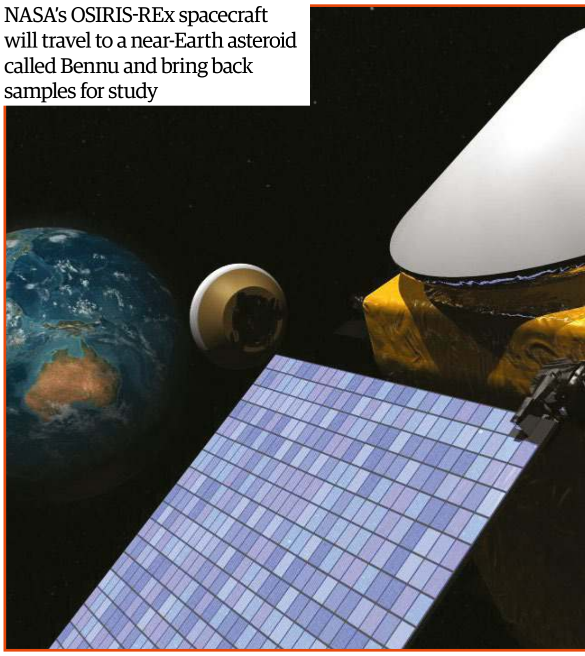
Illustration of an asteroid belt around the bright star Vega based on NASA and ESA observations

He estimates that there would be around two-weeks' notice for the public if a 40m asteroid were on the way. While evacuation may be the answer for a larger asteroid, a smaller fragment of approximately 10 metres would more likely lead to a 'shelter' strategy, similar to a hurricane warning.

The odds of a catastrophic strike on Earth are low, at least for the foreseeable future, but what would happen if a massive asteroid really did hit? The effects would include flying debris, tsunamis, lethal heat and seismic shaking, but violent winds and shock waves resulting from a spike in atmospheric pressure would be the biggest threat to human life, according to a study published in the journal *Geophysical Research Letters* earlier this year. These two threats accounted for more than 60 per cent of deaths in a simulation carried out by researchers from the University of Southampton, who used models to plot 50,000 artificial asteroid strikes around the globe before ranking the lethality of the results.

"The likelihood of an asteroid impact is really low," says Clemens Rumpf, the lead author of its study, "but the consequences can be unimaginable." The good news is that if a potentially lethal asteroid were on a collision course with Earth, we'd know about it. NASA's Planetary Defence Coordination Office (PDCO) oversees the tracking of potentially hazardous asteroids and comets, and would assist the US government, and international agencies, in coordinating a plan if an impact was imminent.

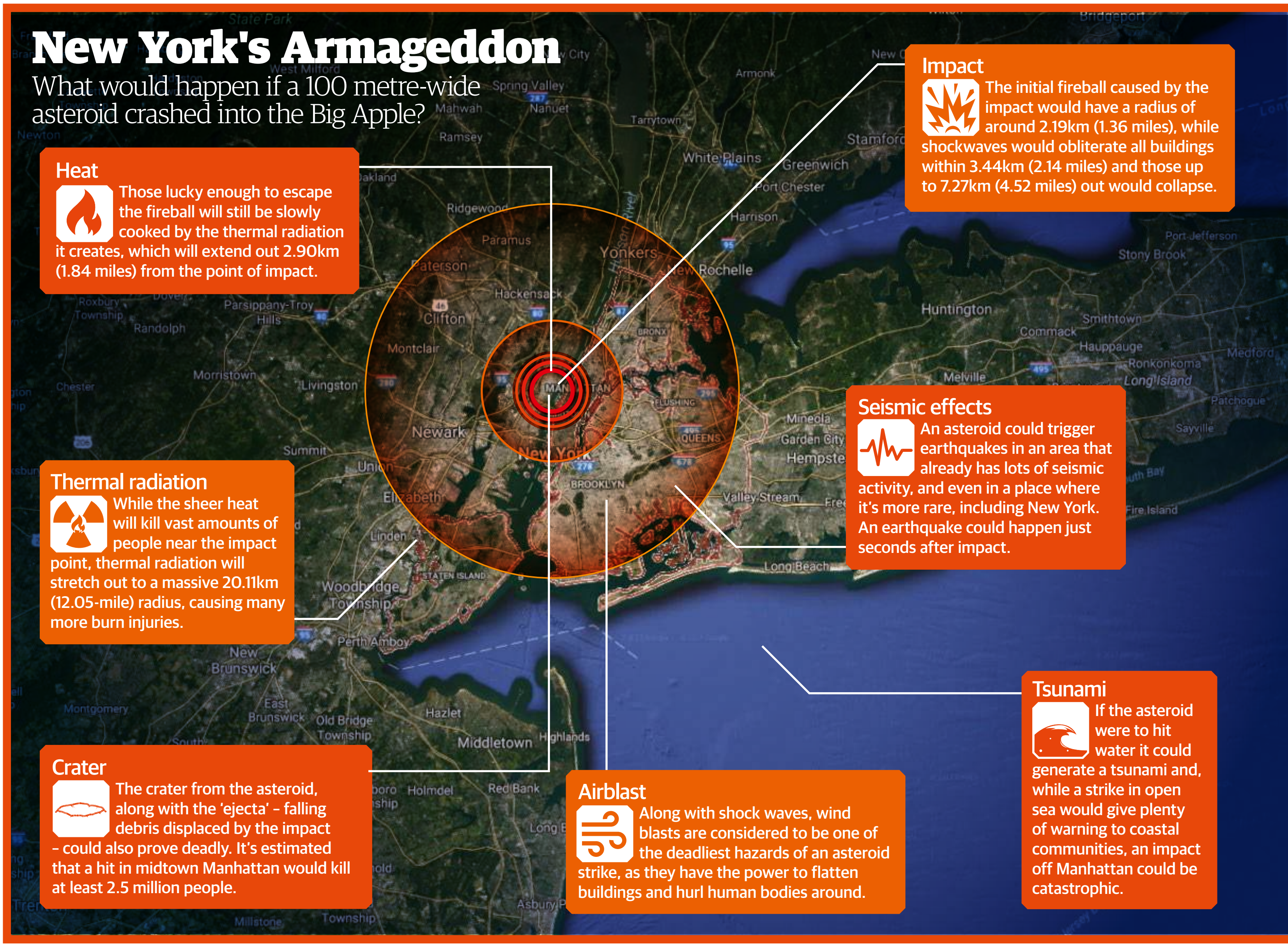
The American space agency has plenty of asteroid-based activity going on at the moment, including its long-serving Wide-field Infrared Survey Explorer (WISE) space telescope, which was originally launched to carry out an all-sky astronomical survey. The telescope was brought out of hibernation and reactivated as NEOWISE in 2013 to hunt down new asteroids. Meanwhile, NASA's OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer), which was launched in September 2016, is set to travel to near-Earth asteroid 101955 Bennu and bring back samples for study. As well as understanding how asteroids could impact Earth, the research could also tell us more about the formation of our Solar System, and even the origin of



NASA's OSIRIS-REx spacecraft will travel to a near-Earth asteroid called Bennu and bring back samples for study

## New York's Armageddon

### What would happen if a 100 metre-wide asteroid crashed into the Big Apple?



**Heat**

Those lucky enough to escape the fireball will still be slowly cooked by the thermal radiation it creates, which will extend out 2.90km (1.84 miles) from the point of impact.

**Impact**

The initial fireball caused by the impact would have a radius of around 2.19km (1.36 miles), while shockwaves would obliterate all buildings within 3.44km (2.14 miles) and those up to 7.27km (4.52 miles) out would collapse.

**Thermal radiation**

While the sheer heat will kill vast amounts of people near the impact point, thermal radiation will stretch out to a massive 20.11km (12.05-mile) radius, causing many more burn injuries.

**Seismic effects**

An asteroid could trigger earthquakes in an area that already has lots of seismic activity, and even in a place where it's more rare, including New York. An earthquake could happen just seconds after impact.

**Tsunami**

If the asteroid were to hit water it could generate a tsunami and, while a strike in open sea would give plenty of warning to coastal communities, an impact off Manhattan could be catastrophic.

**Crater**

The crater from the asteroid, along with the 'ejecta' – falling debris displaced by the impact – could also prove deadly. It's estimated that a hit in midtown Manhattan would kill at least 2.5 million people.

**Airblast**

Along with shock waves, wind blasts are considered to be one of the deadliest hazards of an asteroid strike, as they have the power to flatten buildings and hurl human bodies around.

©NASA Goddard Space Flight Center; NASA/JPL-Caltech; Jay Wong

# In the event of an impact

A step-by-step guide to what happens if an asteroid is hurtling towards Earth

### 1 Potential hazard is spotted

Survey telescopes constantly scan the sky for new NEOs. When spotted and confirmed, they are added to the list for monitoring, and if close to Earth, they get priority for closer inspection.

### 2 Data shared and predictions made

If one of the flagged asteroids appears to be on a course to strike Earth, the information is shared with other observatories and space agencies around the world so that they can compare data.

### 4 Rescue plans and trajectory predictions made

While keeping the information quiet from the public, initial safety plans would be put into place while the asteroid's predicted trajectory is continually updated by observatories around the world.

### 5 The public is informed

If the data shows the asteroid is still on course to hit, governments in the affected areas would issue safety warnings and instructions for the public around two weeks before a strike.

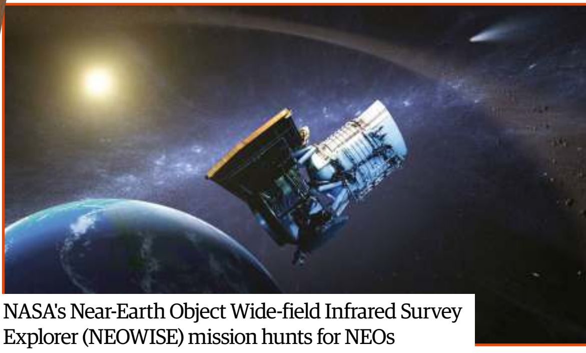
### 3 Governments and rescue agencies informed

If a strike is imminent we would have about three weeks' notice for a 40-metre asteroid. At this point, experts would inform government and rescue agencies so that initial plans can be formulated.

© Ed Crooks

### 6 The world prepares for 72 hours until impact

While preparedness and rescue plans are still being fine-tuned, it's likely that the government would either issue warnings to take shelter for a smaller strike, or evacuate in the case of a bigger impact.



© NASA

NASA's Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) mission hunts for NEOs

organic molecules that lead to the development of life as we know it.

What's more, NASA is using the October flyby of a small asteroid to test its planetary defence network. Asteroid 2012 TC4 measures somewhere between 10 and 30 metres across, slightly larger than the Chelyabinsk space rock, and will safely pass Earth on 12 October. The tiny asteroid will pass no closer than 6,760 kilometres (4,200 miles) from Earth, according to NASA's Center for Near-Earth Object Studies (CNEOS). As part of a collaborative project involving numerous observatories, universities and labs, scientists will work together to nail down the precise trajectory of the asteroid as it approaches Earth. "It will be incumbent upon the observatories to get a fix on the asteroid as it approaches, and work together to obtain follow-up observations that make more refined asteroid orbit determinations possible," says Paul Chodas, manager of CNEOS.

> "It will be incumbent upon the observatories to get a fix on the asteroid as it approaches"
>
> **Paul Chodas**

CNEOS is already involved in computing precise orbits for NEOs, and the flyby should help it to pinpoint any potential asteroid strikes in future. Some of its calculations are already used in simulation exercises, such as the bi-annual Planetary Defence Conference, which brings together experts from around the globe to discuss and run through hypothetical astroid-strike scenarios to develop response plans.

In recent years, governments around the world have been taking the threat posed by asteroids increasingly seriously. In 2017, the White House released the National Near-Earth Object Preparedness Strategy – a 19-page report on what needs to be done to prepare for an impact. The strategy is the precursor to a firmer plan, which at the time of writing, has yet to materialise. NASA has also carried out a series of planning exercises with FEMA (the US government's Federal Emergency Management Agency). What's more, the United Nations-sanctioned International Asteroid Warning Network (IAWN) – an

ESA is developing a fly-eye telescope to completely scan the sky and identify NEOs

> “That is the central issue: find them early. This is the only real way to protect the public” **Dr Ed Lu**

organisation that includes experts from around the world – is also in place to give plenty of warning of an imminent strike.

Also keeping a watchful eye on the skies is the newly formed Asteroid Institute. Created by planetary defence organisation the B612 Foundation, the Institute works with planetary scientists and engineers around the world on asteroid detection and deflection. It also aims to provide opportunities to young scientists to foster talent in this vital field for the future.

“Our goal is to create a dynamic map of the solar system showing the locations and trajectories of the millions of Near Earth Asteroids large enough to destroy a city,” Dr Ed Lu, former NASA astronaut and Asteroid Institute executive director tells **All About Space**. “This is the first step in defending our planet from asteroid impacts – we must first find and track asteroids, and then compute where they are going to be in the future. The B612 Foundation has seen a dramatic increase in the collaboration of governments, public and private institutions to work on identifying asteroids far in advance, so they pose no threat to Earth,” says Lu. “That is the central issue: find them early. This is the only real way to protect the public”.

Awareness of the threat posed by rogue asteroids is certainly increasing, with the UN declaring 30 June – the anniversary of the 1908 Tunguska event – as ‘Asteroid Day’. Aimed at boosting awareness even further, the campaign counts Apollo 9 astronaut Rusty Schweickart and rock star astrophysicist Brian May among its co-founders and is backed by more than 200 high-profile astronauts and astrophysicists, including Lord Martin Rees and Apollo 13 Commander Jim Lovell.

While the idea is to spot any hazardous asteroids before they reach Earth, what if a larger asteroid was on the way? As yet, there is no known weapon system capable of shooting down as asteroid in the minutes or hours before impact because of their sheer velocity. The good news is that if such an asteroid were to emerge we would probably have around a decade to prepare. There are a number of potential defence methods, including firing a nuclear device at a planet-killing asteroid to deflect it, or using a gravity-tractor spacecraft that would fly alongside the asteroid to gradually pull it into an orbit further away from Earth. NASA is already working on DART (Double Asteroid Redirection Test) – a spacecraft that’s designed to smash into an asteroid. “DART would be NASA’s first mission to demonstrate what’s known as the kinetic impactor technique – striking the asteroid to shift its orbit – to defend against a potential future asteroid impact,” says Lindley Johnson, Planetary Defence Officer at NASA. Due to launch by 2021, DART could pave the way for defending against major asteroid strikes.

While emergency management policies across the globe have been refined in recent years with lessons learned from major disasters and terrorist attacks, there is still some way to go to prepare for a massive asteroid strike. But with help from international space agencies and NEO-monitoring organisations, we should be prepared when the worst happens, because it’s not a matter of if an asteroid hits Earth, but when.

A cloud trail left by the Chelyabinsk asteroid after it exploded in 2013

© ESA/A. Baker; M. Ahmetvaleev

## Planet Earth Education

Planet Earth
Education
And
Mobile Stars Planetarium

**Why study Astronomy?**
**How does Astronomy affect our everyday life?**

- **The Sun provides our energy to live and is used for timekeeping.**
- **The Moon causes eclipses whilst its phasing determines the date for Easter Sunday.**
- **Constellations can be used for navigation.**
- **Astronomy is one of the oldest sciences.**

Planet Earth Education is one of the UK's most popular and longest serving providers of distance learning Astronomy courses. We pride ourselves on being accessible and flexible, offering attractively priced courses of the highest standards. Students may choose from five separate Astronomy courses, suitable for complete beginner through to GCSE and first-year university standard.

Planet Earth Education's courses may be started at any time of the year with students able to work at their own pace without deadlines. Each submitted assignment receives personal feedback from their tutor and as there are no classes to attend, students may study from the comfort of their own home.

Of paramount importance to us is the one-to-one contact students have with their tutor, who is readily available even outside of office hours. Our popularity has grown over several years with home educators using our courses for the education of their own children, many of whom have obtained recognised science qualifications at GCSE Astronomy level. With each successfully completed Planet Earth Education course, students receive a certificate.

Visit our website for a complete syllabus of each available course, along with all the necessary enrolment information.

**Courses available for enrolment all year round.**

**☎ 0161 653 9092 www.planeteartheducation.co.uk**

Eddington Lodge

Escape to the North Cornwall Coast

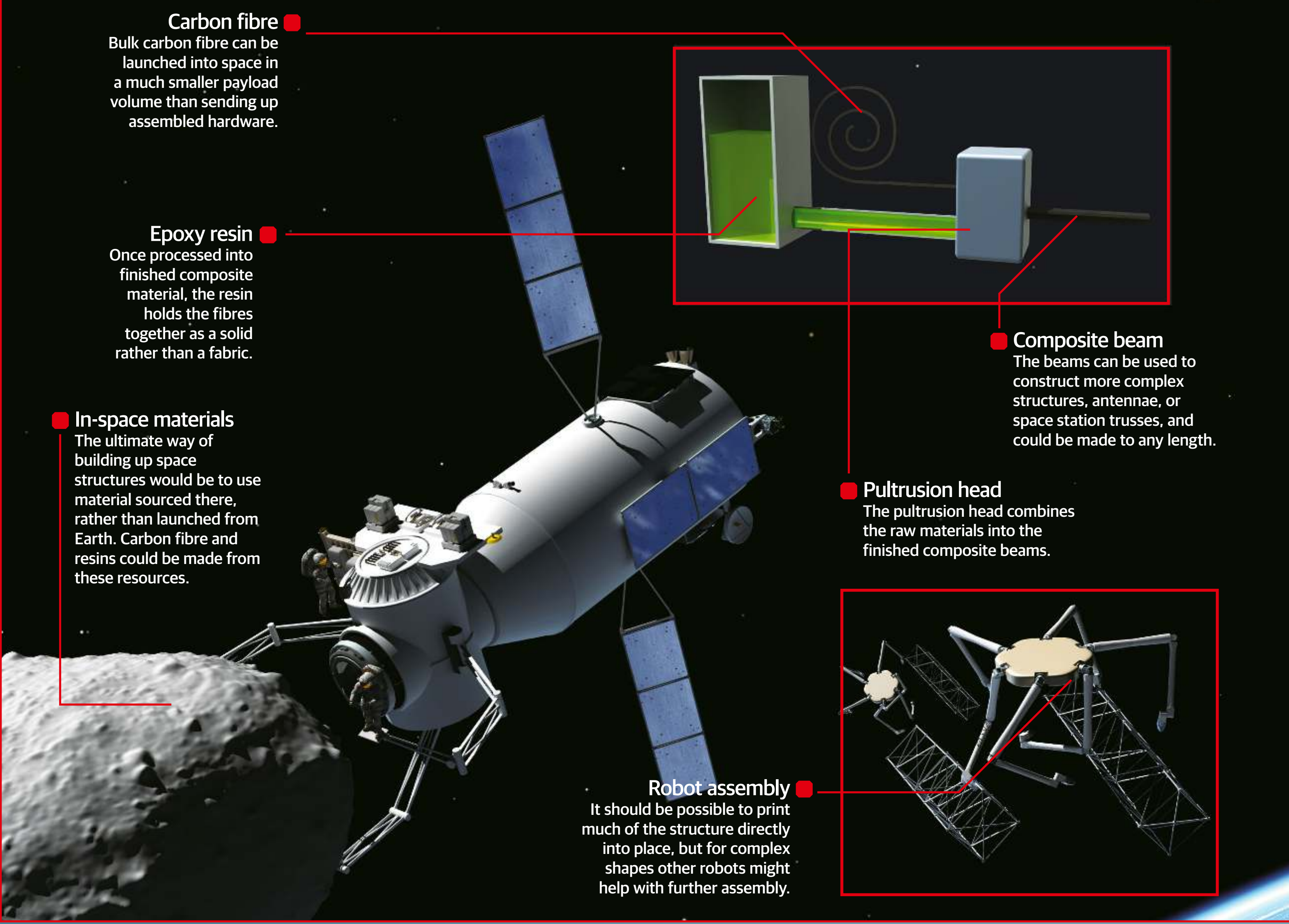
Self catering holidays and short breaks in beautiful North Cornwall. Spend your days at the beach or walking the coastline and nights gazing at the stars in our bespoke observation pods and fully equipped observatory.

www.eddington-lodge.co.uk

# Spinning a Space Station

British company Magna Parva have a machine that could weave the space structures of your dreams

The International Space Station is the largest structure in space so far. It has been painstakingly assembled from 32 launches over 19 years, and still only supports six crew in a little-under-a-thousand cubic metres of pressurised space. It's a long way from the giant rotating space stations some expected by 2001. The problem is that the rigid aluminium modules all have to be launched individually, and assembled in space. Bigelow Aerospace will significantly improve on this with their inflatable modules that can be launched as a compressed



**Carbon fibre**
Bulk carbon fibre can be launched into space in a much smaller payload volume than sending up assembled hardware.

**Epoxy resin**
Once processed into finished composite material, the resin holds the fibres together as a solid rather than a fabric.

**In-space materials**
The ultimate way of building up space structures would be to use material sourced there, rather than launched from Earth. Carbon fibre and resins could be made from these resources.

**Composite beam**
The beams can be used to construct more complex structures, antennae, or space station trusses, and could be made to any length.

**Pultrusion head**
The pultrusion head combines the raw materials into the finished composite beams.

**Robot assembly**
It should be possible to print much of the structure directly into place, but for complex shapes other robots might help with further assembly.

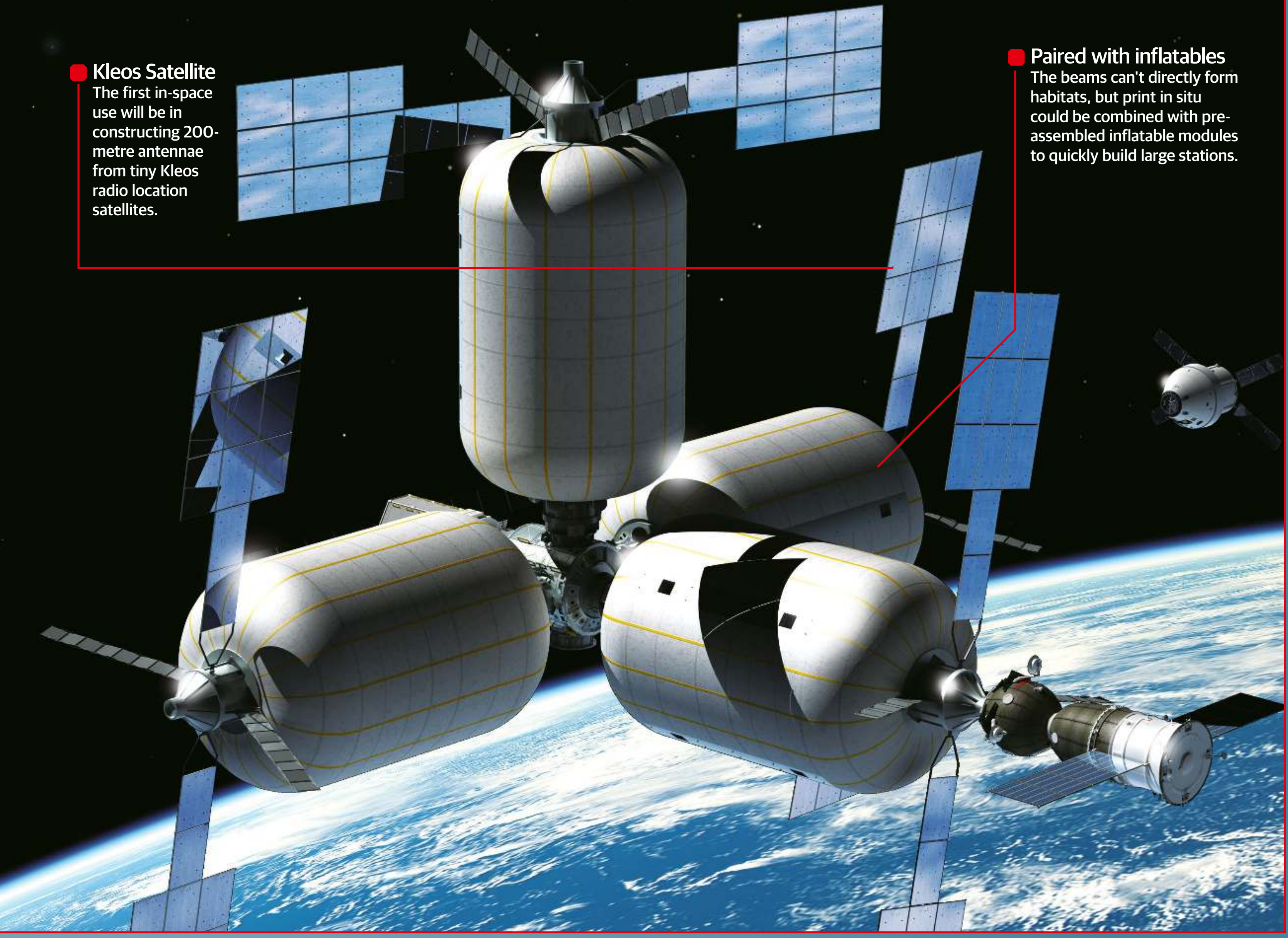
bundle; but a British company has developed a system that could transform space flight, by building structures directly in space.

Magna Parva from Leicester are a space engineering consultancy, founded in 2005 by Andy Bowyer and Miles Ashcroft. Their team have worked on a range of space hardware, from methods to keep Martian solar panels clear of dust, to ultrasonic propellant sensors, to spacecraft windows. But their latest project is capable of 3D printing complete structures in space, using a process called pultrusion. Raw carbon fibres and epoxy resin are combined in a robotic tool to create carbon composite beams of unlimited length - like a spider creating a web much larger than itself. Building structures in space has a range of compounding virtues, it is more compact than even inflatables, as only bulk fibre and resin need to be launched. Any assembled hardware that has to go through a rocket launch has to be made much stronger than needed in space to survive the launch, printed structures can be designed solely for their in space application, using less material still. So you can launch much more 'hardware' for a given size of rocket, and the raw material is used much more efficiently too. In addition, hydrocarbons, from which more fibres and resins could be made, are widespread in space, offering the prospect of being able to build in space, from in-space resources much sooner than we might expect. Either way the system could dramatically reduce the cost, risk and time (the prototype extrudes material at 1 millimetre per second, or a mile every 18 days!) of building large structures in space.

Their prototype has already been successfully tested in vacuum conditions, and will hopefully see its first in-space application for the Kleos constellation. This will be a network of 20 small satellites that will be used for commercial location services by triangulating radio signals. Magna Parva's technique will be used to create 200-metre-wide antennae from a tiny central satellite. At present, the system just creates beams, so for human spacecraft it could be brilliant working in combination with Bigelow's inflatables, forming the structures to dock and connect the pressurised modules. But it may well be possible to form more complex shapes in the future. Perhaps Magna Parva robots might be able to build us the space stations and spaceships of our dreams, spun from fibres made from asteroidal material. It would certainly make space-based solar power (where huge panels make electricity in space and beam it to Earth) more feasible; and perhaps ultimately a similar approach could 'grow' a space elevator down from orbit.

This may be the first time you've heard of Magna Parva, but if their system works as hoped they could have a very big impact on our future in space!

> “Robots might be able to build us the space stations of our dreams, spun from fibres made from asteroidal material"



**Kleos Satellite**
The first in-space use will be in constructing 200-metre antennae from tiny Kleos radio location satellites.

**Paired with inflatables**
The beams can't directly form habitats, but print in situ could be combined with pre-assembled inflatable modules to quickly build large stations.

© Adrian Mann

# Have we
# alrea
# cra
# into
# Andro

# ly shed meda?

Billions of years from now, the Milky Way and our nearest spiral galaxy will collide. According to recent research though, it could be a case of history repeating itself

**Written by Giles Sparrow**

© Tim Abott, CTIO/NOAO

Milkomeda – you may not recognise the name, but if you're a space enthusiast you'll probably be aware of the concept. About 4 billion years from now, our own giant spiral galaxy will begin a vast intergalactic collision with its nearest large neighbour, the Andromeda Galaxy – currently 2.5 million light years from Earth. Head-on collisions between stars will be rare, but the huge clouds of gas and dust scattered among the stars will slam together, triggering a blaze of new star formation. Over many more billions of years, the galaxies will engage in a complex gravitational waltz, ending only when they have merged into the single huge, chaotic ball of stars that some astronomers refer to as 'Milkomeda'.

Evidence for the fate of our galaxy is pretty overwhelming: the Milky Way and Andromeda are already the two heavyweight anchors of the Local Group (a small cluster consisting of several dozen smaller galaxies bound around these major players by gravity), and they are hurtling towards each other at a speed of about 110 kilometres (68 miles) per second. To top it all off, in 2012, careful measurements from the Hubble Space Telescope concluded that the two galaxies' relative sideways motion will not save us from a head-on collision.

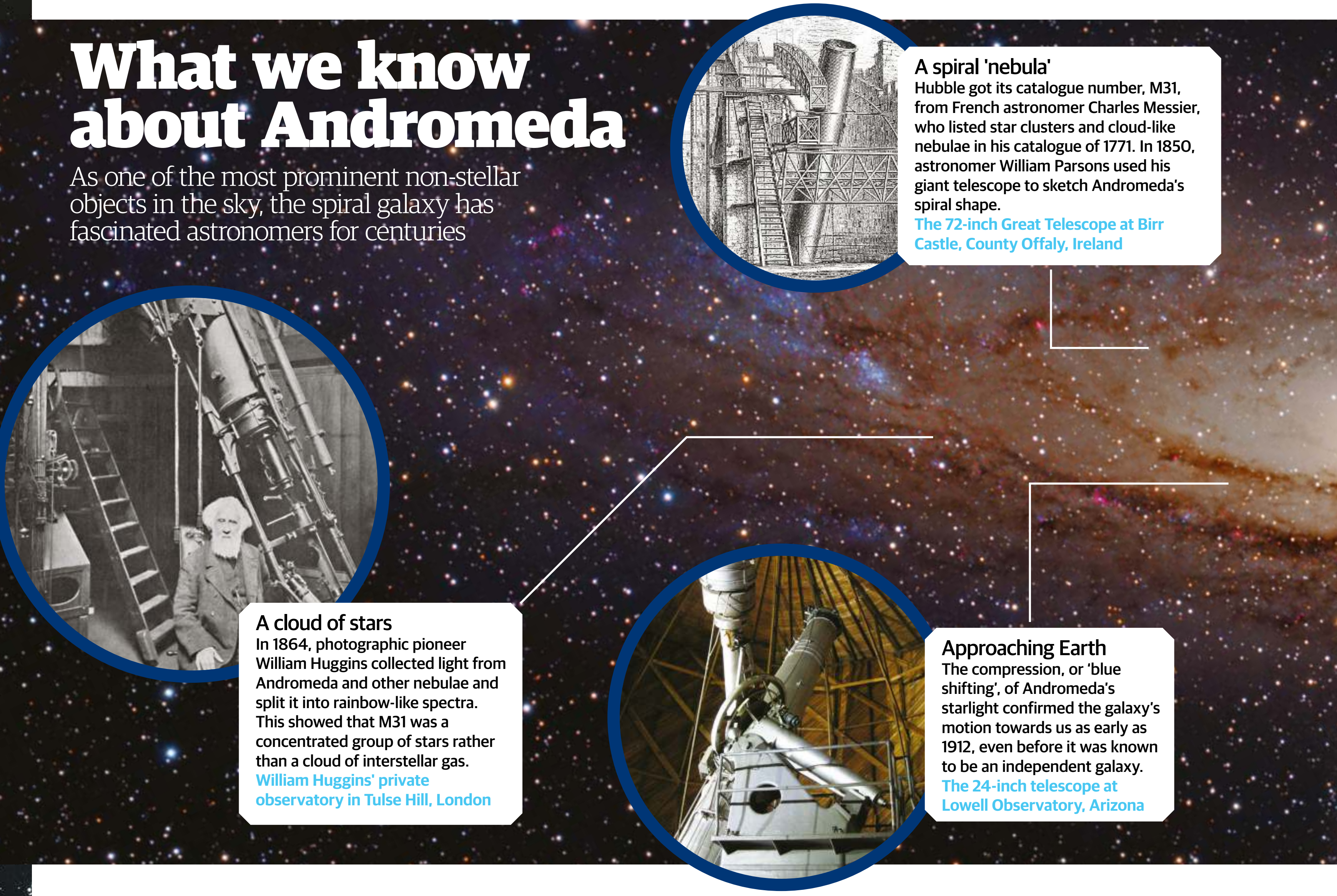
Currently accepted models of physics suggest this smash-up will be the first close encounter between the two giants of the Local Group. But now, new research by a team of international astronomers is revealing evidence that Andromeda and the Milky Way may have met before. If they're right, then it could have radical implications for our understanding of the universe.

It all begins with a well-known problem – the fact that galaxies appear to have much more mass than we can detect through our telescopes. Stars in the outer reaches of galaxies like our own orbit much more quickly than they should, and so do entire galaxies within large clusters. According to Newton's laws of motion and gravity (which have been found to hold true in such situations for more than three centuries), the faster orbits can only be explained if the objects influencing them have much higher masses, and stronger gravity, than they appear to. Modern estimates suggest that almost 85 per cent of the universe's mass is 'missing' – invisible to even the most powerful and sensitive telescopes, and only detectable through the influence of their gravity.

The widely accepted explanation for the missing mass is known as dark matter – a hypothetical material that is not only dark, but also entirely transparent, so that it simply does not interact with light or other radiations passing through it. Ruling out other possibilities, physicists and astronomers have zeroed in on a 'cold dark matter' (CDM) model in which the missing mass is composed of hypothetical new subatomic particles that are relatively slow moving and tend to remain trapped in the gravitational grasp of individual galaxies and galaxy clusters. Despite several decades of ingenious experiments, however, dark matter remains very elusive – yet it is generally assumed to be the only plausible explanation that fits with all the evidence.

But there's another possibility that's rarely spoken of – what if Newton's laws are wrong, or at least incomplete? A century ago, Albert Einstein showed that Newtonian mechanics weren't always the last word in physics, and that different laws applied in situations of extreme motion or acceleration. Einstein even explained how Newton's gravity worked, as a distortion in the shape of space itself. None of this directly affects the evidence for missing mass or the need for dark matter, but if the laws fail in one area, might they fail in others?

In 1981, just a few years after the need for missing mass had become widely accepted, Israeli physicist Mordehai Milgrom put forward an idea that offered



# What we know about Andromeda

As one of the most prominent non-stellar objects in the sky, the spiral galaxy has fascinated astronomers for centuries

### A spiral 'nebula'

Hubble got its catalogue number, M31, from French astronomer Charles Messier, who listed star clusters and cloud-like nebulae in his catalogue of 1771. In 1850, astronomer William Parsons used his giant telescope to sketch Andromeda's spiral shape.

The 72-inch Great Telescope at Birr Castle, County Offaly, Ireland

### A cloud of stars

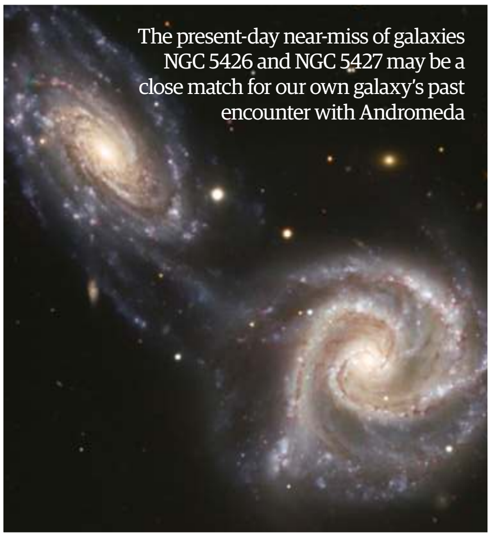
In 1864, photographic pioneer William Huggins collected light from Andromeda and other nebulae and split it into rainbow-like spectra. This showed that M31 was a concentrated group of stars rather than a cloud of interstellar gas.

William Huggins' private observatory in Tulse Hill, London

### Approaching Earth

The compression, or 'blue shifting', of Andromeda's starlight confirmed the galaxy's motion towards us as early as 1912, even before it was known to be an independent galaxy.

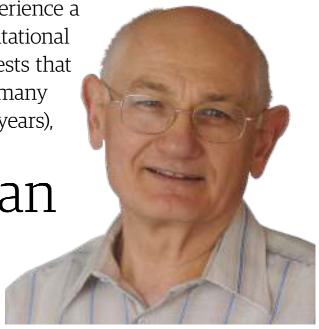
The 24-inch telescope at Lowell Observatory, Arizona



The present-day near-miss of galaxies NGC 5426 and NGC 5427 may be a close match for our own galaxy's past encounter with Andromeda

the potential to do away with dark matter. Milgrom's 'Modified Newtonian Dynamics' (MOND) pointed out a fairly simple tweak to Newton's laws that could enhance either the strength of gravity over large distances, or its effects at extremely small accelerations. Either of these adjustments could account for the faster motion of stars in the outer parts of spiral galaxies, matching well with the best observational evidence.

MOND is perhaps most easily understood in the form that involves an adjustment to Newton's law of universal gravitation. This law says that the strength of gravity diminishes rapidly with distance following an 'inverse square law' (so at twice the distance from a massive, you experience a quarter of the gravitational force). MOND suggests that at great distances (many thousands of light years), the relationship becomes 'inversely proportional' (so doubling the distance merely halves the force). The gravitational force acting on an object plays a key role in determining its speed in orbit, so boosting the strength of gravity on large scales naturally boosts the velocity of objects in orbit. MOND only influences orbits around large masses, because only the gravity of such objects (entire galaxies, or at least their star-packed central regions) persists over large enough distances for its effects to kick in.

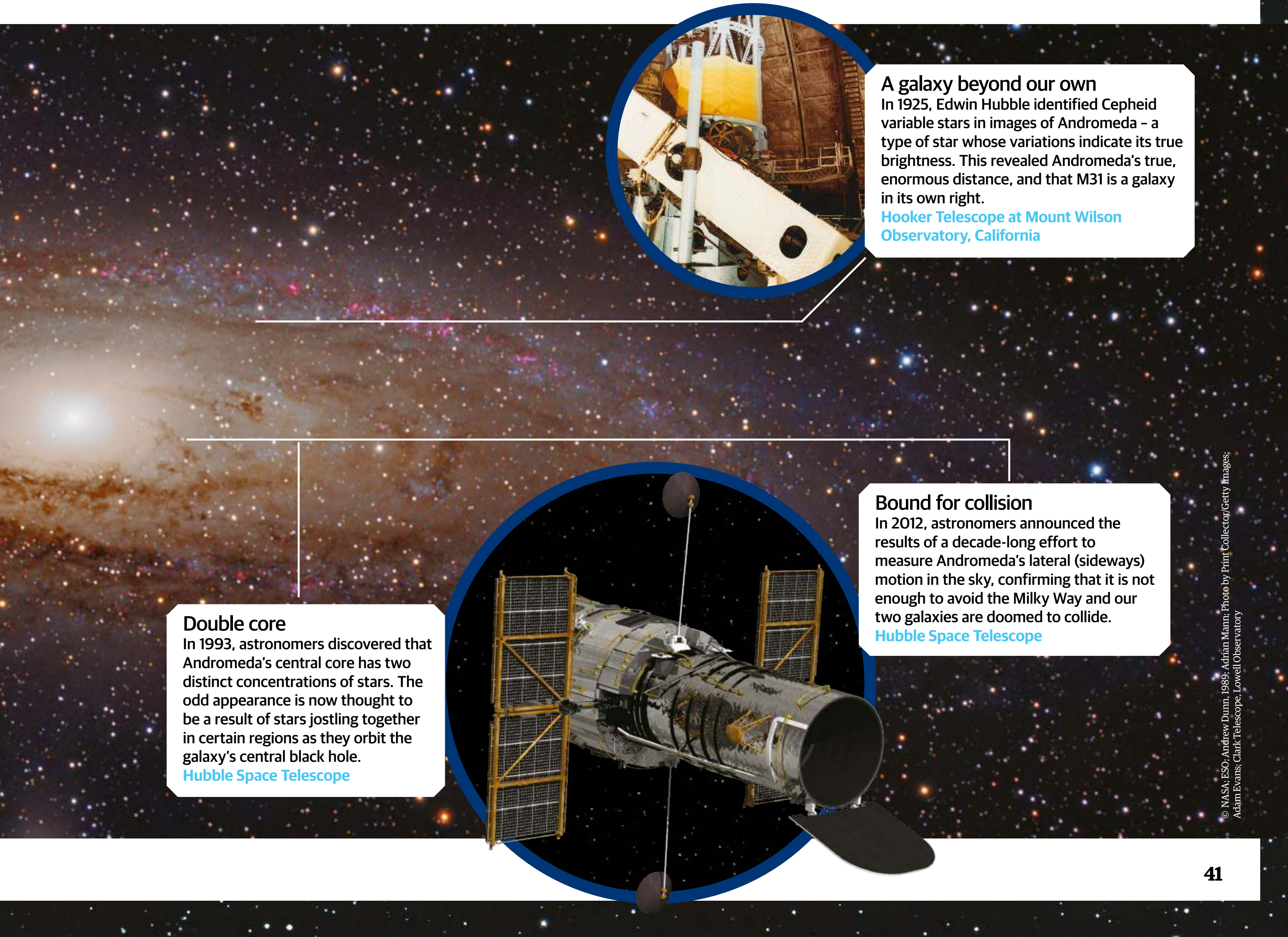


"Einstein showed that Newtonian mechanics weren't always the last word in physics"

The big problem, however, is that by its very nature, MOND is impossible to observe in the lab. Evidence for its effects is therefore only likely to emerge from astronomical observations – and even then, astronomers must find a way to distinguish its possible effects from those of hypothetical dark matter.

That's where Andromeda and our other Local Group neighbours come in – as the nearest galaxies beyond our own, they're the ones we can study in most detail and measure, and an ideal testbed for either proving or, just as importantly from a scientific standpoint, disproving MOND.

"I had always wanted to falsify MOND," explains Dr Hongsheng Zhao of the University of St Andrews, who led the recent investigations. "I knew that in



**A galaxy beyond our own**
In 1925, Edwin Hubble identified Cepheid variable stars in images of Andromeda – a type of star whose variations indicate its true brightness. This revealed Andromeda's true, enormous distance, and that M31 is a galaxy in its own right.
Hooker Telescope at Mount Wilson Observatory, California

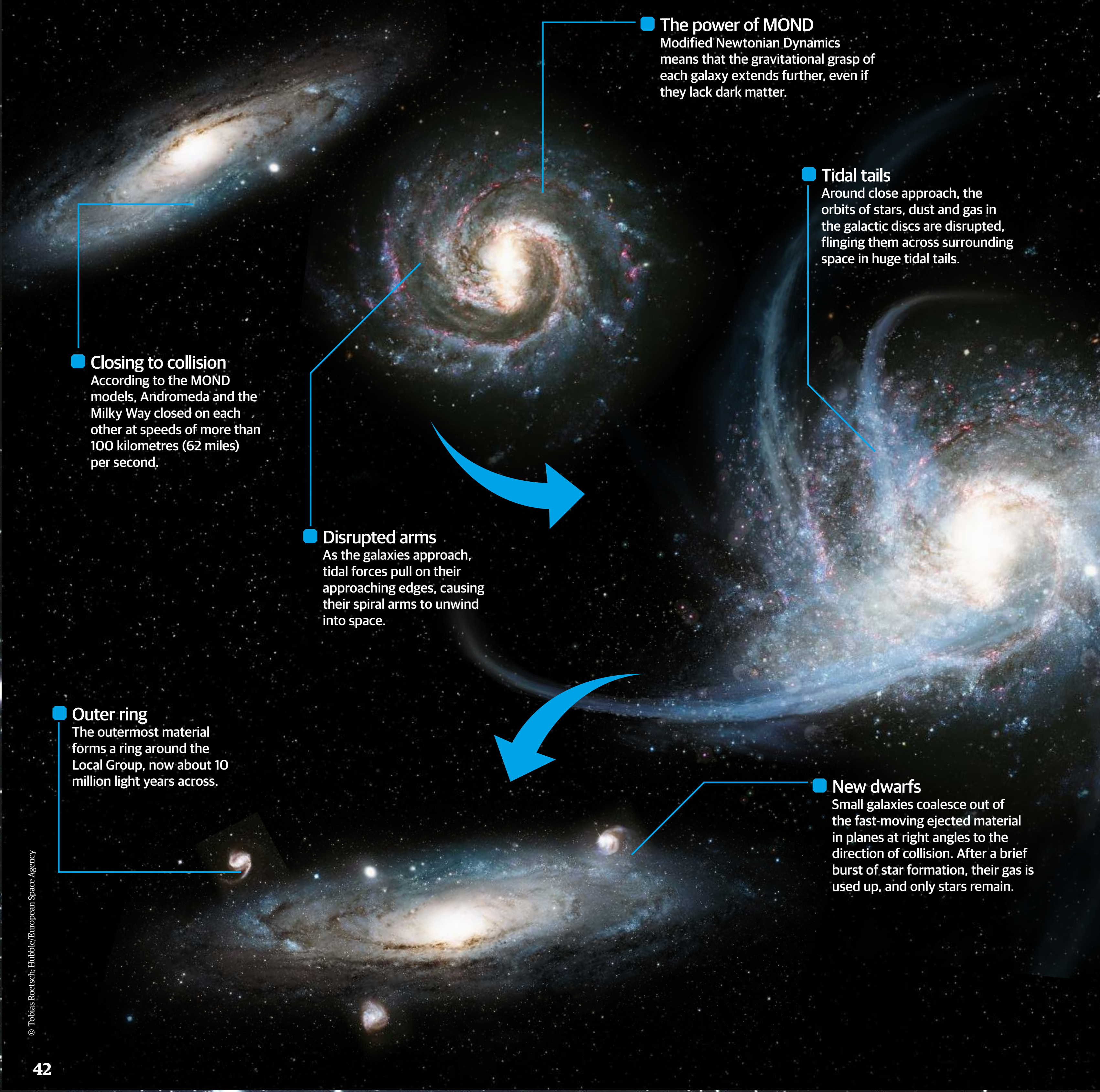
**Bound for collision**
In 2012, astronomers announced the results of a decade-long effort to measure Andromeda's lateral (sideways) motion in the sky, confirming that it is not enough to avoid the Milky Way and our two galaxies are doomed to collide.
Hubble Space Telescope

**Double core**
In 1993, astronomers discovered that Andromeda's central core has two distinct concentrations of stars. The odd appearance is now thought to be a result of stars jostling together in certain regions as they orbit the galaxy's central black hole.
Hubble Space Telescope

© NASA; ESO; Andrew Dunn, 1989; Adrian Mann; Photo by Print Collector/Getty Images; Adam Evans; Clark Telescope, Lowell Observatory

# Evidence of a smash up: How the Milky Way met Andromeda

When the galactic duo collided, tidal effects threw material across the Local Group, but the large galaxies survived more or less intact



**The power of MOND**
Modified Newtonian Dynamics means that the gravitational grasp of each galaxy extends further, even if they lack dark matter.

**Tidal tails**
Around close approach, the orbits of stars, dust and gas in the galactic discs are disrupted, flinging them across surrounding space in huge tidal tails.

**Closing to collision**
According to the MOND models, Andromeda and the Milky Way closed on each other at speeds of more than 100 kilometres (62 miles) per second.

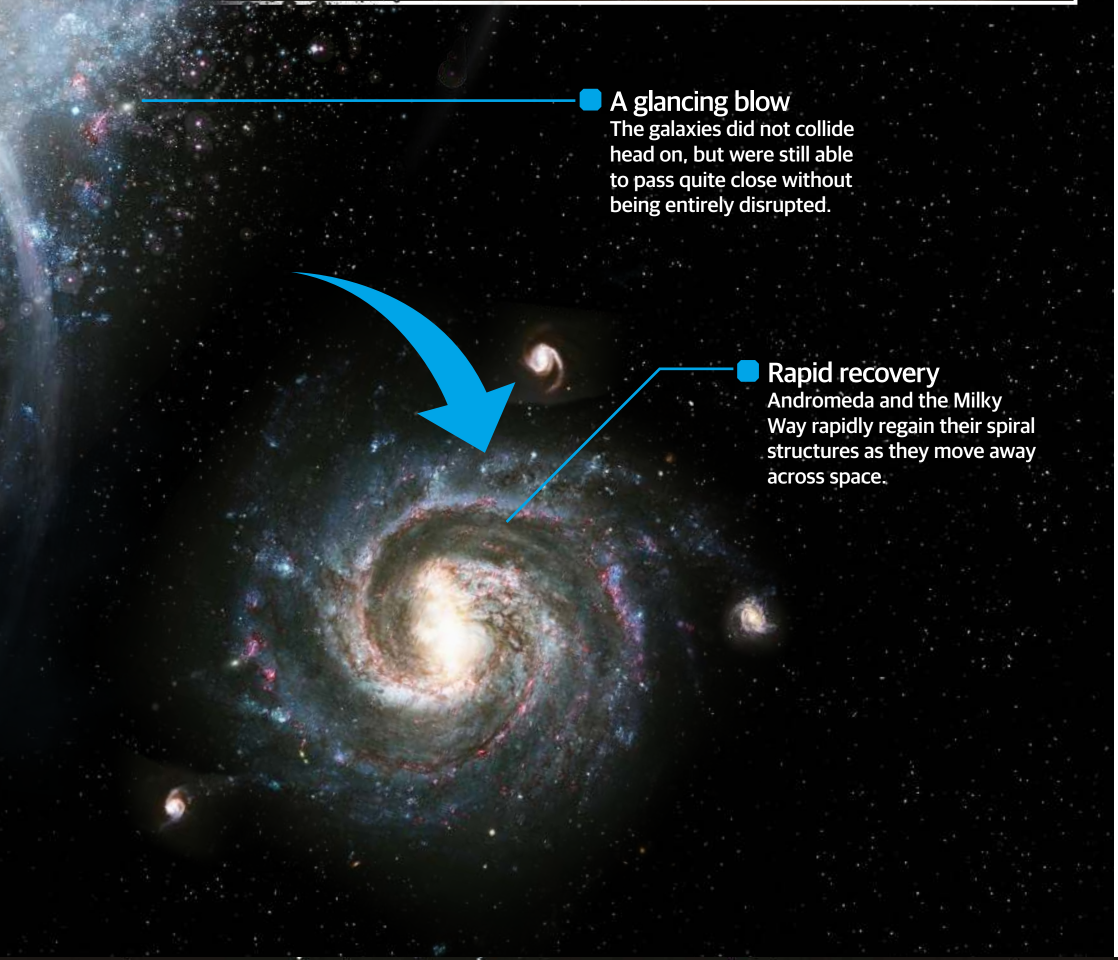
**Disrupted arms**
As the galaxies approach, tidal forces pull on their approaching edges, causing their spiral arms to unwind into space.

**Outer ring**
The outermost material forms a ring around the Local Group, now about 10 million light years across.

**New dwarfs**
Small galaxies coalesce out of the fast-moving ejected material in planes at right angles to the direction of collision. After a brief burst of star formation, their gas is used up, and only stars remain.

© Tobias Roetsch; Hubble/European Space Agency

When galaxies collide, individual stars usually miss each other, but star-forming gas clouds are rammed together triggering huge waves of new star formation, as seen in this close-up of the Antennae galaxies



**A glancing blow**
The galaxies did not collide head on, but were still able to pass quite close without being entirely disrupted.

**Rapid recovery**
Andromeda and the Milky Way rapidly regain their spiral structures as they move away across space.

MOND it is quite easy to pull M31 [the Andromeda Galaxy] and the Milky Way close together because their gravity is enhanced, and I thought this was a definite problem for the theory."

Collisions in the past look, at first glance, like a problem for MOND, because both the Milky Way and Andromeda appear to be more-or-less perfect spiral galaxies. From countless other examples in the universe, astronomers know that collisions between spirals can dramatically affect their structure, unwinding their spiral arms and flinging stars, gas and dust across interstellar space even if they do not lead to a direct merger. At first glance neither the Milky Way nor Andromeda show signs of trauma from such events.

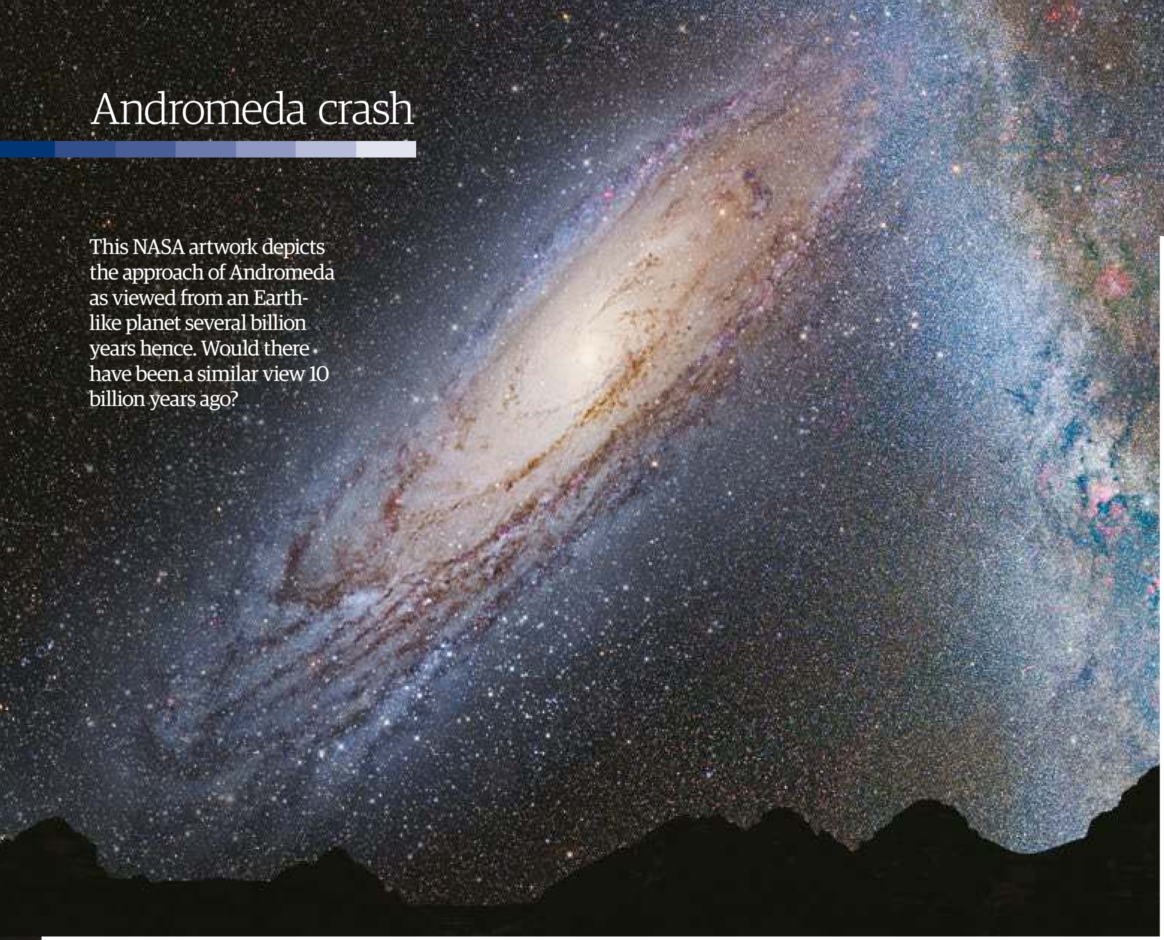
But there's more to the structure of the Local Group than meets the eye, and this is what piqued the interest of Zhao and his collaborators. "The cold dark matter model says that structures around the Milky Way are supposed to be random," he explains, "but, a few years ago, we learned that various structures in the surroundings appeared to be correlated, as if they've been influenced by past interactions. This gave me the idea of investigating MOND further."

> "I found there was a certainty of a close passage between M31 and the Milky Way in the past" **Dr Hongsheng Zhao**

The most important of the structures in question are the dozens of tiny 'dwarf galaxies' that account for nearly all of the Local Group's membership (though very little of its weight). If these formed from collapsing matter at the same time as the larger galaxies, then we should expect to find them scattered more or less at random across the 10-million-light-year volume of the Local Group, but instead, astronomers have found that nearly all the dwarfs are close to the major spirals.

In 2012, Alan McConnachie of Canada's Herzberg Institute of Astrophysics produced the first detailed survey of the motion of 100 dwarf galaxies in and around the Local Group. Supported by the Scottish Universities Physics Alliance, Zhao and his PhD student Indranil Banik used these measurements to model the expected motion of the smaller galaxies under the influence of both the Milky Way and Andromeda's gravity, and the general expansion of the universe, discovering that many of the smaller galaxies are moving away from us much faster than should be expected.

Banik and Zhao's models of a MOND-enhanced Local Group provided a possible explanation by bringing the two giant galaxies close together in their past. "We found there was a certainty of a close passage between M31 and the Milky Way in the past, though whether that was a head-on hit or a fly-by, we couldn't tell from the first principles. However, we knew that a head-on hit would be ridiculous, since it would destroy the galaxies' flattened discs [home to



This NASA artwork depicts the approach of Andromeda as viewed from an Earth-like planet several billion years hence. Would there have been a similar view 10 billion years ago?

a spiral galaxy's star-forming regions, including the spiral arms themselves]. On the other hand, a fly-by could explain a few good things in the Local Group. It could throw out materials to the distances where we see satellite galaxies distributed."

Despite making it more likely that the two large galaxies have come together in the past (perhaps 10 billion years ago) by enhancing their gravity over large distances, the MOND model also explains why the effects of the encounter differ from those in traditional models. By disposing of the need for huge amounts of dark matter in a vast halo around the galaxy, it reduces the galaxies' close-range tendency to merge together.

"Galaxy collisions are slightly 'sticky', what's called gravitational friction," explains Zhao. "The sticky volume is huge for a CDM model, as big as a halo is. But for MOND, it's only as big as the galaxy's disc is, as there are no real halos. So CDM halos are bulky and slow, and MOND galaxies are lean and fast."

As a result, significant amounts of material can be flung out from the galaxies (giving rise to dwarf galaxies with unexpected motions), but the spirals themselves speed past each other, resisting the tendency to coalesce and soon recovering their pristine structure. It takes several billion years for gravity to slow and reverse their motion, drawing them back towards another collision.

Dr Zhao and his colleagues published their initial research in 2013, and have been busy since. Working with researchers at the University of Bonn and elsewhere, they have identified new lines of evidence to support the idea of a past collision between the Milky Way and Andromeda. For instance, modelling the distribution of the fast-moving dwarfs suggests they should all have originated from a single plane during the encounter (something hard to account for in traditional models).

And now, there's evidence from further afield than these relatively nearby dwarfs. "Indranil has found the high-velocity structure, much further than satellites, in an expanding ring of small galaxies 10 million light years in diameter. They are like the ring of raindrops flung out by spinning an umbrella, and their motion can also be explained by an M31-Milky Way fly-by. Fast expanding and rotating Local group structures are enormously more likely to emerge from encounters between fast MOND-style galaxies."

Beyond this, the team recognise the need to show how the theory operates on other scales - is there evidence for more frequent but less traumatic collisions in larger galaxy clusters, for example? "Some evidence must be shown to convince people on the scale of clusters," agrees Zhao. "Another student of mine, Alistair Hodson, has built some extended models, which fit a sample of clusters. We are improving the tool boxes and doing more realistic simulations all the time, but, of course, we are always short of people and machines."

Of course, this is all a long way from getting the scientific establishment to accept the controversial MOND in its entirety. Marrying MOND with general relativity presents its challenges for theoretical physicists, and the vast weight of scientific opinion still favours dark matter. But, perhaps the work of Dr Zhao and his colleagues is a first step - and it's certainly raised intriguing evidence that our galaxy and Andromeda had a much closer past relationship than we ever suspected.

## Changing the laws of the cosmos

If there was a smash-up between the galactic giants, then it could alter our understanding of the universe

### No need for dark matter?

**Our current theory: Dark matter makes up about 85 per cent of the mass of the Universe.**

If evidence for a past collision between Andromeda and the Milky Way stands up, then it can only be explained by a theory like Modified Newtonian Dynamics, which does away with the need for dark matter.

### Gravity stays strong over large distances

**Our current theory: Gravity falls off according to an inverse square law at all distances.**

MOND suggests that the fall-off in gravity's effects becomes inversely proportional at large distances, significantly boosting the strength of gravity in the outer reaches of individual galaxies.

### Galaxy collisions are frequent but brief

**Our current theory: When galaxies collide, their huge halos of dark matter create a gravitational anchor that tends to make the collision 'sticky'.**

Without dark matter, collisions are less sticky - galaxies move away from all but the most direct collisions at speed, regaining separations of millions of light years before being pulled back towards each other.

### The history of the Local Group

**Our current theory: The Local Group galaxies formed with a random distribution and it's taken more than 10 billion years for gravity to draw them together.**

If the models are correct, then the Milky Way and Andromeda first collided about 10 billion years ago, flinging out arcs of stars, gas and dust to form fast-moving dwarf galaxies across the Local Group.

© ESO/B. Tafreshi (twanight.org); Chandra; NASA/ESA:

# THE RETURN OF **SUPER PLAY**

100% FOR SUPER NINTENDO PLAYERS
スーパープレイ
BACK! FOR ONE FINAL MISSION
INDEPENDENT SUPER NINTENDO MAGAZINE
Super PLAY
ISSUE 48
OCTOBER 2017
STAR FOX 2
FOX McCLOUD FINALLY RETURNS TO THE SNES!
Has the wait been worth it?
NEW REVIEWS OF SNES CLASSICS!
Contra III
EarthBound
Final Fantasy III
Secret Of Mana
Super Mario Kart
Super Mario World
Super Metroid
Yoshi's Island
And more...
SNES MINI HANDS-ON TEST INSIDE
WIN ORIGINAL WIL OVERTON ART, A SNES MINI CONSOLE AND MORE!
SUPER EXPRESS ● ANIME WORLD ● IMPORT REVIEWS ● WHAT CART?
future
retro GAMER
PC Engine
Import Icon
Discover how NEC's miniature console made the west green with envy
SURVIVING NIGHT TRAP
11 ATARI ST ESSENTIALS
NAVIGATING MOON PATROL
MAYHEM MONSTERS

**IT'S BACK!**

Get the new issue of **Super Play**, celebrating the launch of the SNES Mini, exclusively with the new edition of **Retro Gamer**.

Available at www.myfavouritemagazines.co.uk

## ON SALE NOW

facebook.com/RetroGamerUK twitter.com/RetroGamer_Mag

*For one month only!

# Have we found the first exomoon?

Sifting through data from NASA's Kepler Space Telescope, astronomers believe that we could have picked up the first signal of an alien moon. Co-discoverer and astronomer Alex Teachey reveals if we should be getting our hopes up

**Interviewed by Lee Cavendish**

**Why do think that exomoons play such an important role in understanding our universe?**

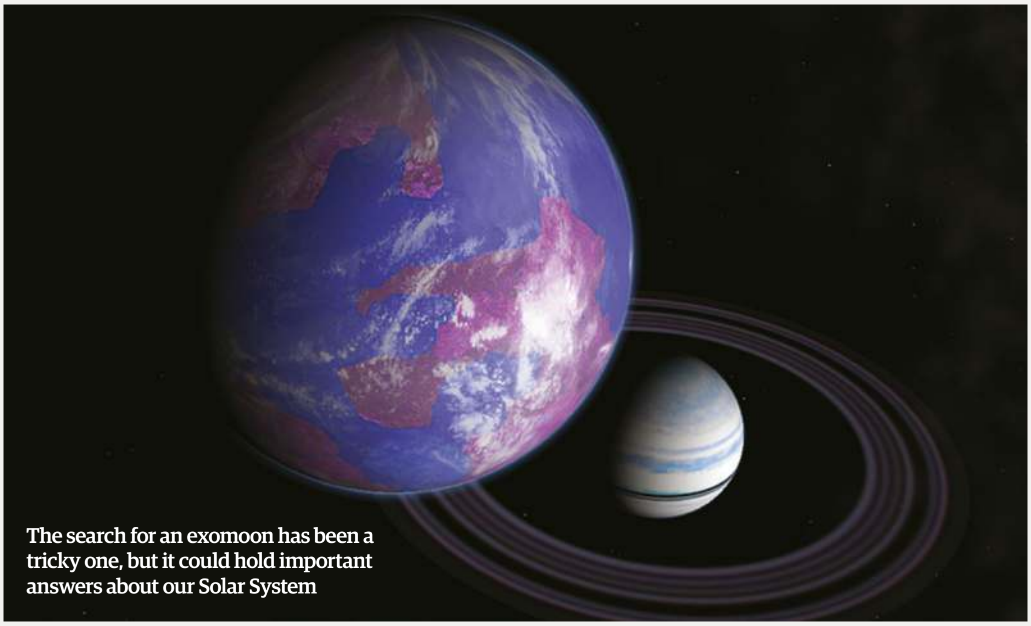
I think that there's a couple of reasons why we're so interested in exomoons. First of all, I think that they could really tell us a lot about the formation of our Solar System, and the formation of other solar systems. Certainly they tell us about the system we see them in, but the question always arises about life evolving on Earth. Were these circumstances on Earth very common across the galaxy, or were they very special? I think that it's very much an open question.

I think exomoons can play a part in answering that question, because we've seen moons all over the place in our Solar System, and there's good reason to think they could be elsewhere. Until we see moons, it's very much an open question whether we've got an unusual formation history, or whether this is something that happens all over the place.

So that's one thing, then, I would say that we are still very much interested in the idea of habitable moons. The candidate we identified in our paper, I would expect it to be a habitable moon, as we think it's quite large. More generally, I think people are very much interested in these questions, because what if these moons are habitable?

There are interesting places in our own Solar Systems, such as Europa, Enceladus, Titan and other places that are very intriguing, and could even be habitable. If similar moons turn out to be habitable in other parts of the galaxy, then this expands the number of places where life could arise on.

> "If similar moons turn out to be habitable in other parts of the galaxy, then this expands the number of places where life could arise"



The search for an exomoon has been a tricky one, but it could hold important answers about our Solar System

**How would you describe the signal that you found from Kepler-1265b-I, and how does that compare with an exoplanet signal?**

So when we look at exoplanets, we are looking for 'transits'. These are dips in the starlight we see when a planet passes in front of the star from our point of view. This is sort of a curved, trapezoid shape. When we're looking for the moons, we're looking for another dip in the transit associated with the moon. So, when the planet is blocking out starlight, the moon moves in front [of the star] and blocks the starlight as well. As you can imagine, as the planet is going around the star like clockwork - and the moon is going around the planet - every time you see the planet transit, the moon is probably going to show up in different places within the vicinity of the planetary transit.

What we were looking for was these dips, due to the presence of the moon. That's what you'd expect to see if you saw a moon in your data, and that's what we think we saw in the Kepler-1265 system. I have been stressing all over the place that this is a candidate, but until we observe it with Hubble, it really isn't a sure thing. But so far, the tests we've run to rule out the presence of a moon - this system has passed all these tests. We think that the Kepler data is inconclusive, it's tantalising, but we really need the Hubble data to confirm the presence of this moon.

**What has been done to rule out the possibility of it being an instrumental artefact?**

There was an exomoon candidate that came along a couple of years ago and my advisor, David Kipping spent many years looking for exomoons. They thought they had found a [exomoon] candidate, and they starting looking at the individual pixels in Kepler's CCD image. [After their analysis] what they thought was an exomoon signal was really just a weird thing to happen to the detector at that moment. So we definitely looked at that to try and rule it out.

If you have lots of transits to work with, you'll model some of the transits, and leave some of the transits out of the model, then try to basically predict the morphology of those last transits. So in other words, you build the model based on the certain pieces of the data, and if that model is good, it should

**INTERVIEW BIO**

**Alex Teachey**

Alex Teachey is a National Science Foundation (NSF) Graduate Research Fellow at Columbia University, working alongside Professor David Kipping. Alex has been studying and searching for exoplanets and exomoons for many years now, as he scours the data collected by the Kepler Space Telescope. He is currently searching for signs of the world's first alien moon detection, which he might have just found. He has worked at both the American Museum of Natural History and the National Radio Astronomy Observatory.

NASA's Kepler Telescope inside the Hazardous Processing Facility at Astrotech in Titusville, Florida

do well in fitting the data you haven't already fit through.

In this case, we only had three transits, so what we had to do then is split up the transits in half, and fit it that way. It was a bit unusual to have to do it, because there were so few transits, but the model seemed to work out very well.

But, if you give your model enough complexity, you can always find a better fit for the data. Hence why you have to penalise that model to make sure you are accounting for that built-in error, and we definitely had to do that with the moon model. But, even accounting for these sorts of things, the moon model seems to do pretty well.

**What else could this signal be? Are 'blips' like these a common occurrence?**

Firstly, we tried to rule out the instrumental artefact as best as we could, and then in our proposal for observing with Hubble, we also briefly examined other possibilities like, could this be a star spot? It can't really be a star spot, because that just wouldn't show up the way we're seeing it. I would say there is still a possibility that there could be some sort of instrumental strangeness that happened. I really do think we've done our due diligence, but there is always a chance that something got by us.

Also, there's something called 'detrending' - this is when you have long-term trends in the data that are from both from the instrument, and subject of the star. You have to collect those out, and be pretty careful of how you do it. Basically, when you see a [processed] transit, it's mostly flat, and then there are these clear dips due to the planet. The real data doesn't look that way. There is a correcting produce of the long-term trends you see in the data. So there's always a chance that something strange has happened in that process as well. The good news is we've fit a model through the data, we seem to have a pretty good idea of what this moon would look like, and what that allows you to do is then project into the future. We now have some sort of prediction as to what we're looking for in the October transits.

If we find a good fit this would be really strong evidence that we've made a successful prediction. But, at this point, it's tough because there are so few transits, we only have three, and we definitely would of liked more than that. So we're just approaching with an abundance of caution, until we observe it with Hubble we're just not going to be totally convinced.

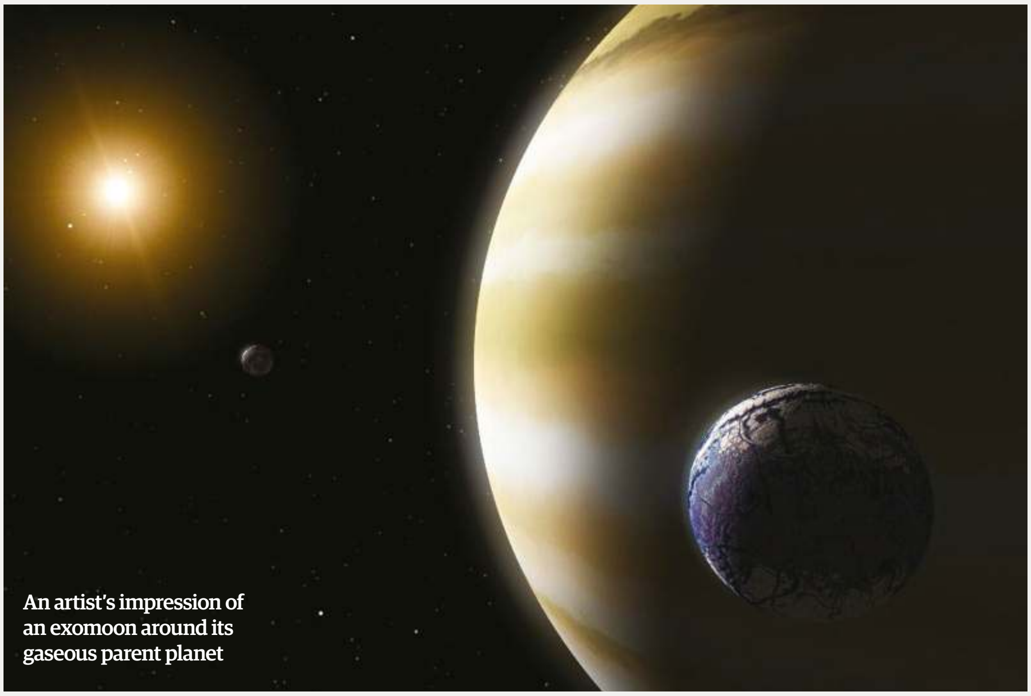
There are some people out there that make a prediction, I'm thinking of these 'Planet Nine' guys Brown and Batygin, and they are exceedingly confident in their predictions. I believe they even said they're 100 per cent positive that Planet Nine exists, and I'm sort of envious of their certainty! Because until we observe this thing [with Hubble], I'm not going to sleep easily. But we're optimistic, as I've said we've done our due diligence, but we have to wait and see.

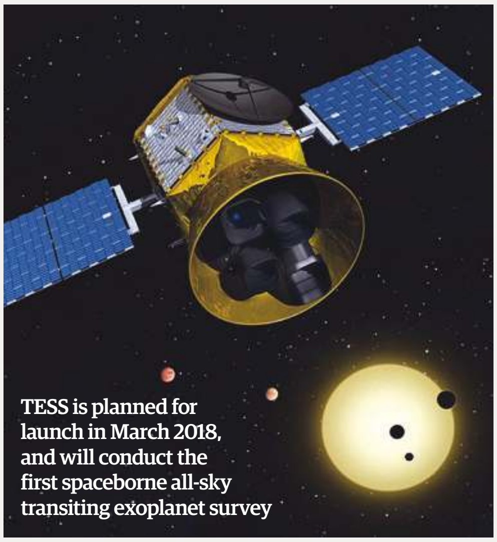
**Have you been able to estimate, or deduce, any physical properties about Kepler-1625b's exoplanet and potential moon system?**

I think we mentioned it briefly, but we're reluctant to go into great detail about it, because these things could change when the Hubble observations come down. I'll point out that the star [size] changed from Data Release 24 to Data Release 25. The data didn't really change, but there was a new analysis for the size of the star. It went from being smaller than the Sun to larger than the Sun, and when you measure a transit, the dip in the starlight tells you the size of the planet in relation to the star. So if the star gets bigger, the planet gets bigger. The old estimate for the size of the star claimed the planet to be about half the size of Jupiter. Then, once the star got bigger with better data analysis, that made the planet about the size of Jupiter. It also made the moon much larger then it would have been otherwise. Before it would have been about the size of the Earth, and then it would have been about the size of Neptune. This is based on the estimate for the stellar parameters. It's sort of an unusual system, not something like we would have expected to see, and that again is a reason why

> "It's sort of an unusual system, not something like we would have expected to see"

Hubble will turn its sights to Kepler-1625b-I in October 2017


An artist's impression of an exomoon around its gaseous parent planet

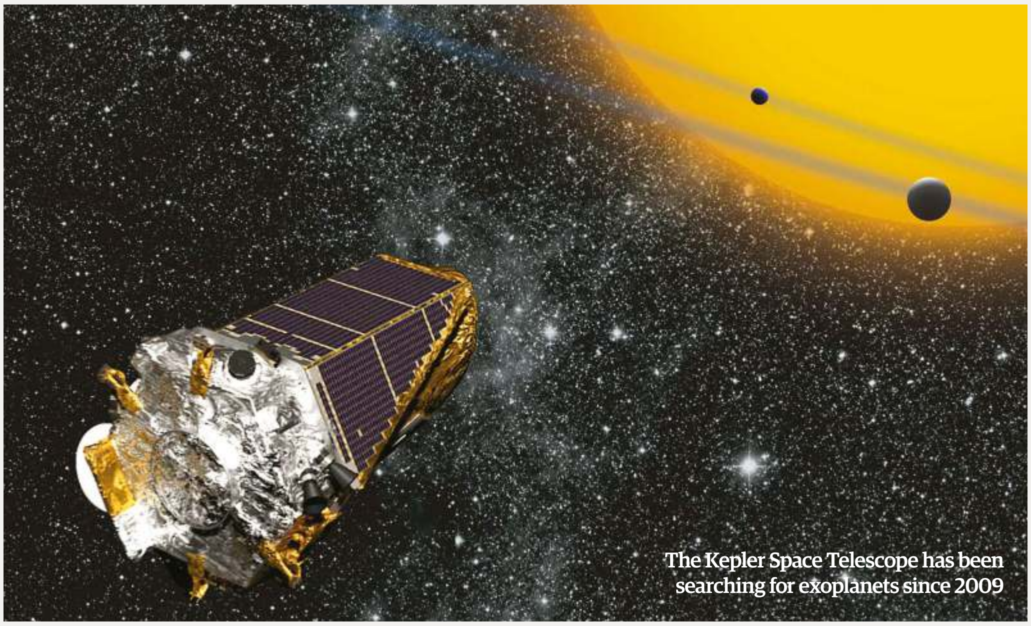

TESS is planned for launch in March 2018, and will conduct the first spaceborne all-sky transiting exoplanet survey

> "I still think that there is stuff to be mined out of the Kepler data, but it's going to be tricky. I think we're going to have to get even cleverer about how we detect exomoons"

we had some reservations about this thing.

**So as you've already mentioned, you've acquired time with the Hubble Space Telescope in October of this year. What are your plans with this limited time on Hubble?**

We've got 26 orbits on the telescope, and we'll just be staring at the star. The thing about transits is that you have to monitor it from the beginning to the end. The planet is quite far away from the star, as it has an orbital period of about 287 days. That means the transit is going to dip for quite a while, as it is about an 18-hour-long event. In the case of looking for a moon, we have to make the observations longer than that, because we're looking at the star before the planet ingresses (starts passing in front of the star) and we also have to look at it when it egresses (leaves the face of the star). So it's quite a lengthy observation we're making, but we'll just keep staring at the star the entire time, monitoring it and taking repeat exposures. But we've got priority access to the data for six months, and we're going to try and do our best to analyse it, and get our paper out in that time.


The Kepler Space Telescope has been searching for exoplanets since 2009

**With the constant uprising in exoplanet exploration, how do you think exomoon exploration can be improved?**

I'll tell you the truth, it's going to be really tough. The thing about Kepler is that it's been staring at one patch of the sky for four and a half years, and you really need at least two transits to characterise a exoplanet. So it has to transit twice in four and a half years, and so you can do the maths, these are going to be short-period planets close in to the star. So it appears that moons are quite rare in that region, but, of course, that's perfectly in keeping with what we see in our own Solar System. All the big moons (with the exception of our own) are in the outer Solar System, Kepler just wasn't able to probe that region at all, and that's it for Kepler.

**Are there any exomoon missions on the way?**

I think the next most exciting mission coming up is the Transiting Exoplanet Survey Satellite (TESS). This is going to be an exciting mission because it's going to scan the whole sky, and it is going to have enormous exoplanet yield. In this case, it will look at an area in the sky for 30 days and move on, so you won't be able to probe the outer Solar System, which is going to be tough. Going forward, it's going to be quite tricky. I think we're going to have to get even cleverer about how we detect exomoons.

© NASA ; Jack Pfaller; MIT

**FREE GIFT**
**Worth up to £22.99**

NASA
HUBBLE
SPACE TELESCOPE
1990 onwards (including all upgrades)
Haynes
Owners' Workshop Manual
An insight into the history, development, collaboration, construction and role of the Earth-orbiting space telescope
All About Space
MARS

# Free Haynes Manual

## Subscribe by 30 October to receive your free gift

Delve into the fascinating story of one of NASA's longest-serving space telescopes with this unique, complete guide to Hubble. With a wealth of photographs, diagrams, cutaways and charts, uncover what it takes to build, launch and operate the greatest mission of all time.

**Gemma Lavender,** Editor

✓ **Never miss an issue**
13 issues a year, and you'll be sure to get every single one

✓ **Delivered to your home**
Free delivery of every issue, direct to your doorstep

✓ **Get the biggest savings**
Get your favourite magazine for less by ordering direct

All About Space | Subscription offer

# Pick the subscription that's perfect for you

MOST FLEXIBLE

## Six month subscription

✓ Automatic renewal – never miss an issue

✓ Pay by Direct Debit

Recurring payment of £26 every 6 months, saving 20% on the retail price

DIRECT Debit Instruction to your Bank or Building Society to pay by Direct Debit

Originator's reference 7 6 8 1 9 5

Name of bank

Address of bank

Postcode

Account Name

Sort Code

Account no

Please pay Future Publishing Limited Direct Debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with Future Publishing Limited and, if so, details will be passed on electronically to my Bank/Building Society. Banks & Building Societies may not accept Direct Debit instructions for some types of account

Signature

Date

GREAT VALUE

## One year subscription

✓ Great offers, available world-wide

✓ One payment, by card or cheque

A simple one-off payment ensures you never miss an issue for one full year. That's 13 issues, direct to your doorstep

☐ UK £51.90 (saving 20% on the retail price)

☐ Europe €78.64 ☐ USA $87.08 ☐ Rest of the world $96.75

## Pay by card or cheque

Pay by Credit or Debit card

☐ VISA Visa ☐ MasterCard Mastercard ☐ AMERICAN EXPRESS Amex

Card number

Expiry date /

Pay by Cheque

I enclose a cheque for £

Made payable to *Future Publishing Ltd*

Signature

Date

## Your information

Name

Telephone number

Mobile number

Email address

☐ Please tick if you want to receive any communications from Future and its group companies containing news, special offers and product information.

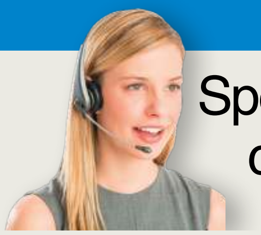
Address

Postcode

Please post this form to

**Future Publishing Ltd**, 3 Queensbridge, The Lakes,
Northampton, NN4 7BF, United Kingdom

## Order securely online **myfavouritemagazines.com/spaceh**



Speak to one of our friendly customer service team

Call 0344 848 2852

These offers will expire on
30 October 2017

Please quote code **AASPS17G**

This offer entitles new subscribers to receive a copy of the Nasa Hubble Space Telescope manual from Haynes worth £22.99. Gift stock is subject to availability and Future reserve the right to withdraw this offer at any time should stock run out. Offer code AASPS17G must be quoted to receive this special subscription offer. Prices and savings are compared to buying full priced print issues. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magtandc Offer ends 30 October 2017.

## YOUR QUESTIONS ANSWERED BY OUR EXPERTS

In proud association with the National Space Centre
*www.spacecentre.co.uk*

**Sophie Cottis-Allan**

**National Space Academy Education Officer**
Sophie studied astrophysics at university. She has a special interest in astrobiology and planetary science.

**Josh Barker**

**Education Team Presenter**
Having earned a master's in physics and astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

**Tamela Maciel**

**Space Communications Manager**
Tamela has a degree in astrophysics and writes for the National Space Centre Blog. She has eight years' experience in science communication.

**Lee Cavendish**

**Staff Writer**
Lee holds a degree in observational astronomy. He's a regular observer of the night sky and enjoys documenting the wonders of the universe.

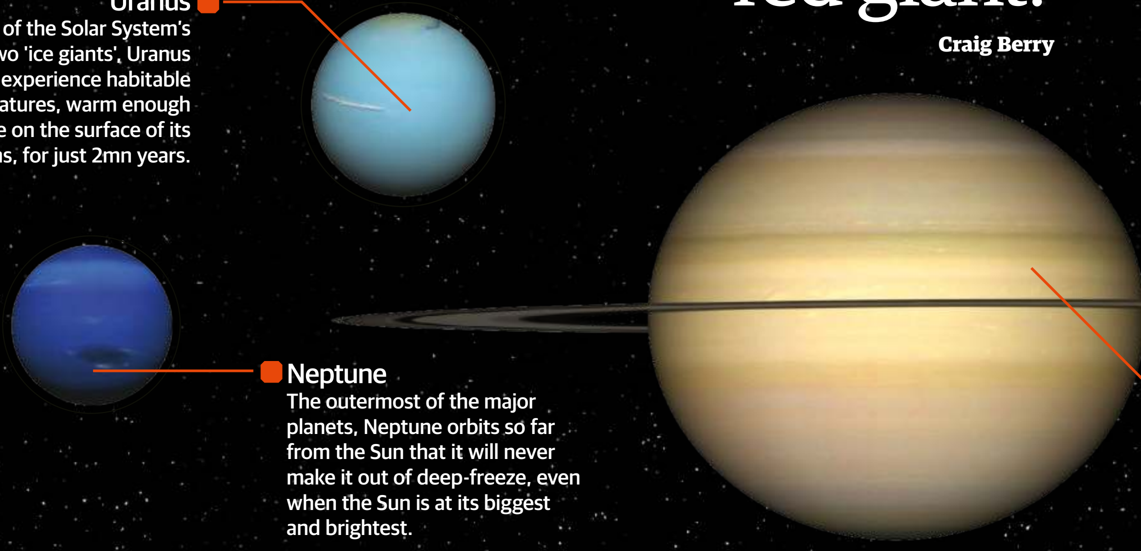
**Robin Hague**

**Science Writer**
Robin has a degree in physics with space technology and a master's in hybrid rocket engine design. He contributes regularly to All About Space.

SOLAR SYSTEM

# How will the Solar System look when our Sun evolves to a red giant?

**Craig Berry**



**Uranus**
The inner of the Solar System's two 'ice giants', Uranus will experience habitable temperatures, warm enough to melt ice on the surface of its moons, for just 2mn years.

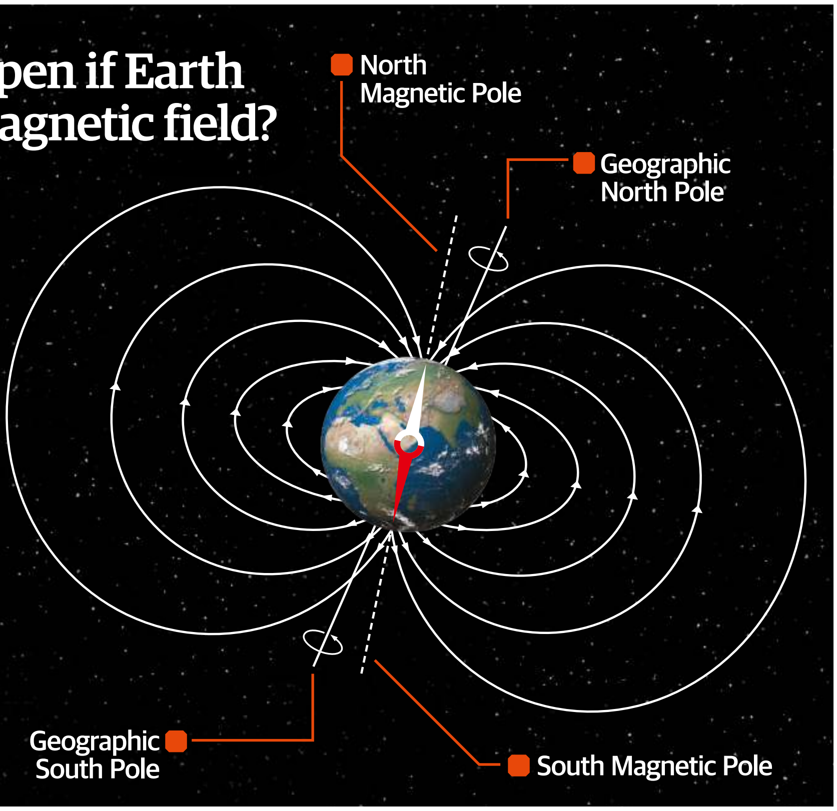
**Neptune**
The outermost of the major planets, Neptune orbits so far from the Sun that it will never make it out of deep-freeze, even when the Sun is at its biggest and brightest.

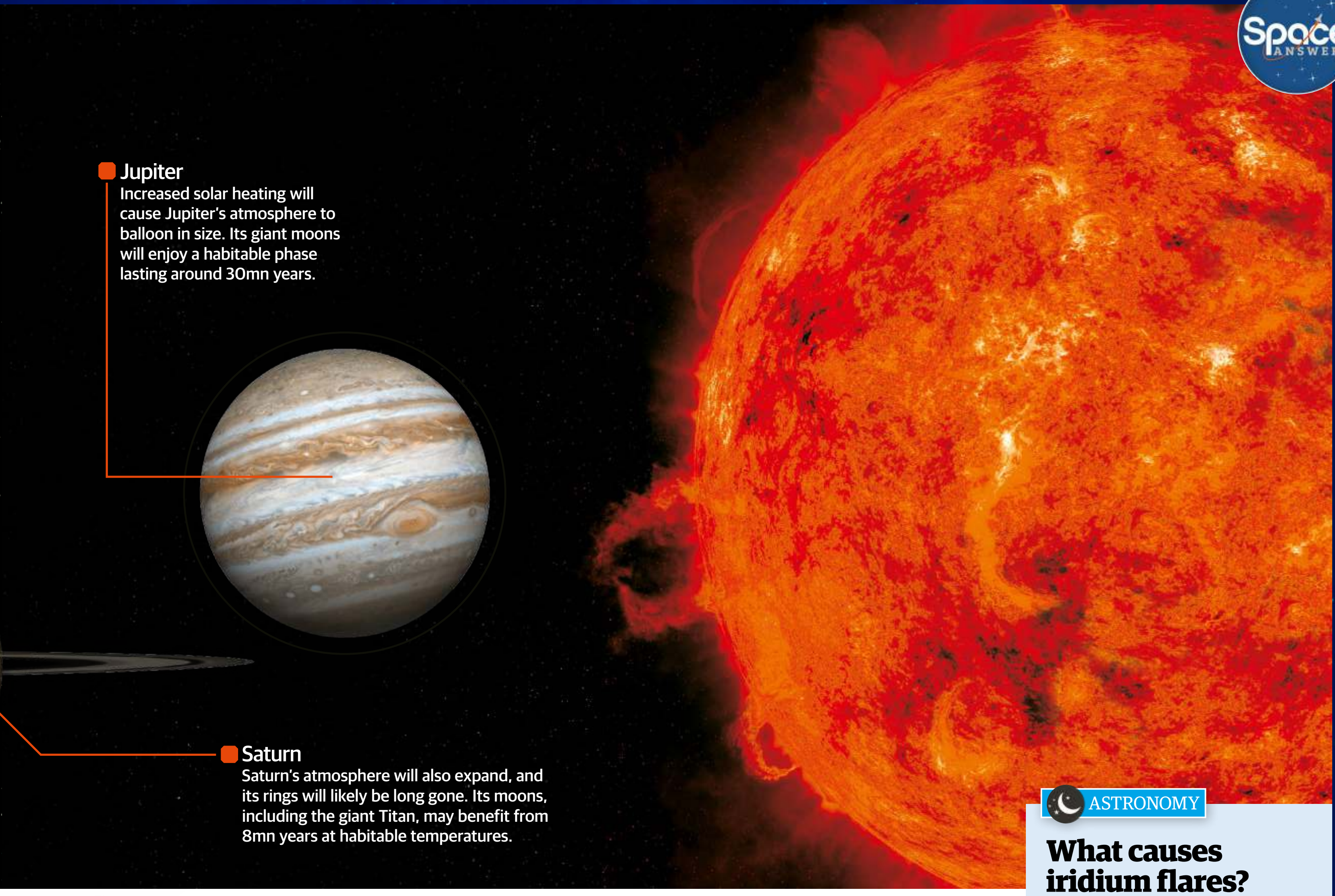
SOLAR SYSTEM

# What would happen if Earth had a stronger magnetic field?

**Mark Hunt**

One large change would be our interaction with radiation from space. If the field were to grow stronger, the 'radiation traps' known as the Van Allen belts would likely increase in size and density. More radiation would be funnelled in by the magnetic field at the poles. This would cause the aurora to be much bigger and possibly last longer. The radio interference caused by this could cause issues with radio communications. It isn't just space-based features that would be altered. Radiation from space plays a key role in the Earth's weather. These rays being blocked would result in changes in weather and possibly large changes to our climate overall. Depending on the change in strength we could see a whole host of wide ranging changes. **JB**





**Jupiter**
Increased solar heating will cause Jupiter's atmosphere to balloon in size. Its giant moons will enjoy a habitable phase lasting around 30mn years.

**Saturn**
Saturn's atmosphere will also expand, and its rings will likely be long gone. Its moons, including the giant Titan, may benefit from 8mn years at habitable temperatures.

SPACE EXPLORATION

# Are there any new missions to Saturn planned?

**Carl Stork**

Cassini has been wildly successful in exploring Saturn and its moons, but there are still many mysteries. Scientists would love to return to Saturn's moon Titan, and explore its methane lakes by air, land, and even boat! Enceladus, with its icy water plumes, is another tantalising moon of Saturn and may harbour microbial life in its subterranean oceans. Many future Saturn missions have been proposed to NASA and the European Space Agency (ESA), but at the moment, none have been funded. Realistically it'll be in the 2030s or even 2040s before we see a new spacecraft arrive at the ringed planet. In the meantime, all eyes are on Jupiter. NASA's Juno mission is currently in orbit around Jupiter, and both NASA and ESA are developing future missions to Jupiter's icy moons Europa and Ganymede. These moons may also harbour primordial life. Look out for ESA's JUICE (JUpiter ICy moons Explorer) mission and NASA's Europa Clipper, both due for launch in the 2020s. **TM**

> "Scientists would love to return to Saturn's moon Titan, and explore its methane lakes by air, land, and even boat!"

© NASA; ESA; Andrzej Łuczak

ASTRONOMY

## What causes iridium flares?

**John Venzon**

Relatively frequently we will get an inquiry about a sudden bright object appearing in the night sky, before dimming and disappearing mysteriously a few seconds later. This is an Iridium flare, named for the fleet of communication satellites with silver coated antennae angled at 40 degrees from the body of the craft. When the angle between the Sun, satellite and observer is just right, sunlight can reflect from these antennae back to the observer, temporarily outshining even Venus in the night sky. It does not take long for the satellite to pass overhead, and the angle of reflection to be altered so that an observer at a certain location on the Earth can no longer see the flare, and so the dramatic light will quickly disappear from view. **SA**

DEEP SPACE

# What gives a star its colour?

**Sarah Boyle**

Certain stars appear to have a tint of colour. Generally, the colour of a star is an indication of the temperature of its surface. Stars are giant nuclear reactors, producing energy that excites or gives energy to electrons. When these subatomic particles lose this energy, they emit radiation, mainly as visible and infrared (heat). The hotter the star, the greater the average energy of the radiation emitted. The possible colours of visible light are found within a spectrum, or rainbow. Blue light has a shorter wavelength and higher energy than red light, indicating that the surface temperature of a blue star is higher than that of a red star. And our own Sun? A yellow, mid-temperature star! **SA**

ASTRONOMY

# Why do some people observe the aurora from an aeroplane?

**Keegan Fulton**

There is no real difference in what you see when viewing the aurora from the ground or a plane. However, it may be easier to see them while flying. The aurora can be tricky to view from the ground, already elusive, it is also hindered by light pollution and the weather. By flying up above the clouds, aurora chasers hope to leave some of that behind. At the height at which most large planes fly a large amount of cloud cover is bypassed. This means that the aurora can be seen even in inclement weather. The height off the ground also helps with light pollution. On board a plane you are far away from the streetlights you find down on the ground, which can make these natural light shows easier to spot. **JB**

DEEP SPACE

# What fills the space between galaxies?

**Jeff Panko**

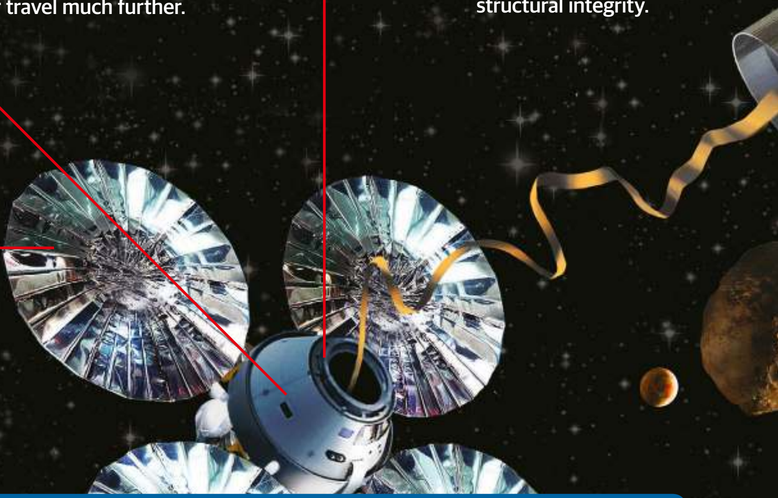
The space between galaxies certainly appears to be largely empty, but there is some visible material present, and this is very unevenly distributed - a bit like a cosmic spider's web. It is actually the unseen that dominates space and dictates where normal matter (mainly hydrogen and helium gas) will be found. Gravitational evidence suggests that an invisible component, currently known as dark matter, surrounds all galaxies. Advanced computer simulations show that gravitational effects of this dark matter create long, thin filaments along which normal matter forms into galaxies. If you were to look along these filaments, you would see some sparse gatherings of matter between more dense galaxies, but look away from these filaments and you will see almost nothing - just extremely low density gasses. **SA**

Dark matter's existence is the leading theory of the space between galaxies

SPACE EXPLORATION

# How would 'space fishing' work as a sample-and-return mission?

**Claire Bennett**



**Openings**
Once the rocket has entered the target, rock samples will shoot through the openings and be secured. The interior of planetary bodies is extremely interesting to space scientists.

**Analysis**
One plan is for the spacecraft to be filled with instruments which will enable analysis of the samples to occur while the spacecraft is travelling.

**Body**
This has to be very strong because if it crumples upon impact, the sample could be damaged or lost. One option is foam epoxies to reduce the blow and maintain structural integrity.

**Spacecraft**
The lack of a landing requirement will enable the spacecraft to run with much less fuel or travel much further.

**Thrusters**
The spacecraft will use thrusters and its current speed to pull the rocket back towards the ship, helping the wire in its task.

SOLAR SYSTEM

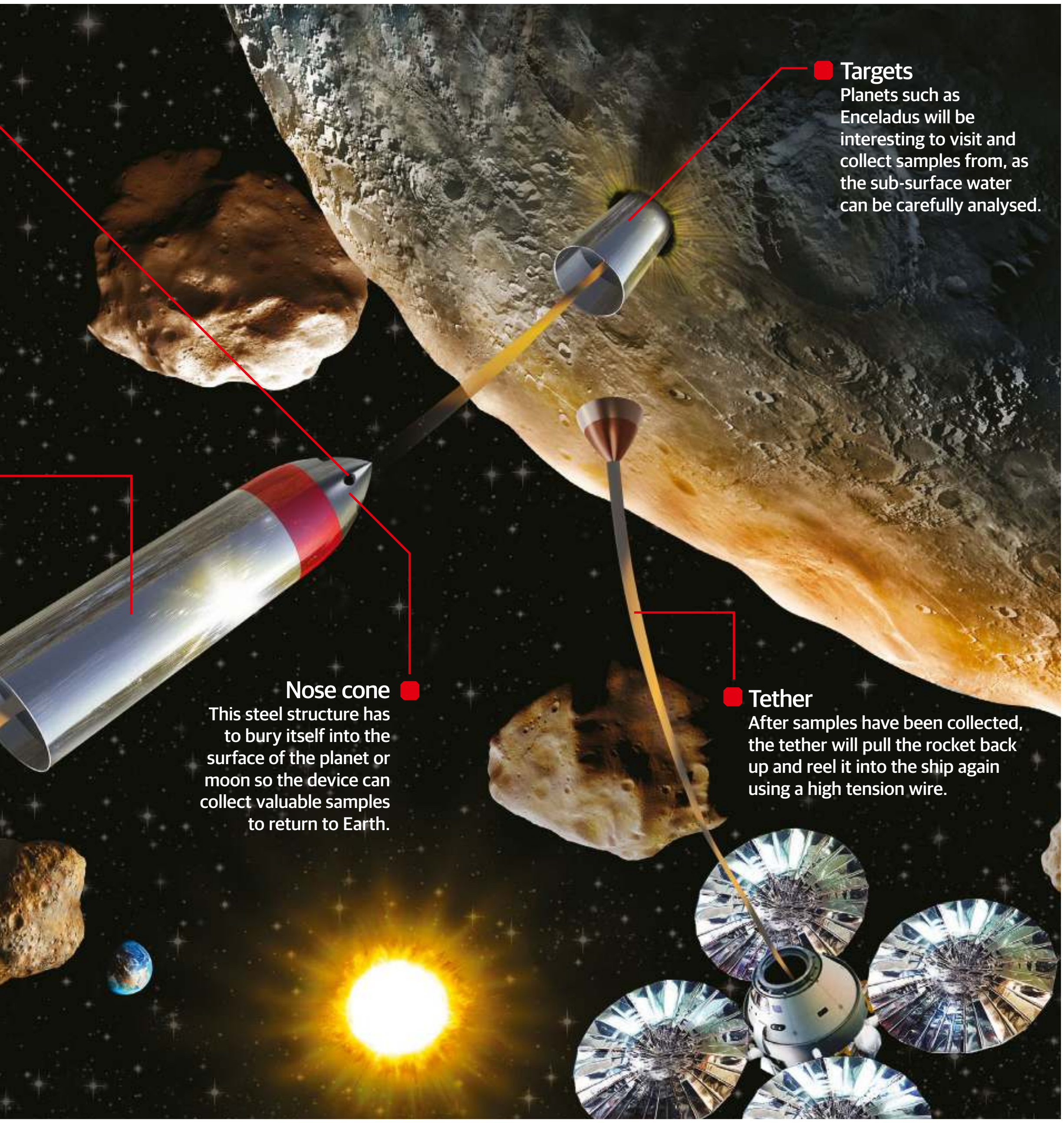
# Will Pluto ever be reinstated as a planet?

**Joshua Danna**

If you learned names of the planets before 2006, you would have counted Pluto as the ninth planet in the Solar System. But in August 2006, the International Astronomical Union reclassified Pluto as a dwarf planet, along with a growing list of other small, rocky worlds that circle the Sun. This wasn't an arbitrary decision. Since its discovery in 1930, Pluto has been an oddity - its orbit is very elliptical and skewed at an angle, and it is relatively tiny compared to the size of its five moons. In the early 2000s, astronomers began to discover new rocky bodies in the Solar System with a similar or larger mass than Pluto, forcing the community to either add in many new planets or redefine what makes a planet. In the end, it was decided that rocky bodies that aren't big enough to clear their orbits of debris would be considered dwarf planets. Under this definition Pluto failed to make the cut, and joined Eris, Ceres and other worlds as dwarf planets. It is unlikely these will ever be reclassified as planets again, but that certainly doesn't mean they're not fascinating places to visit! The New Horizons mission has revealed Pluto to be an active, mountainous world full of unexpected surprises, as has the Dawn mission to Ceres. **SA**

> “Pluto failed to make the cut, and joined Eris, Ceres and other worlds as dwarf planets”

Pluto is no longer the smallest planet, but one of the largest dwarfs!



**Targets**
Planets such as Enceladus will be interesting to visit and collect samples from, as the sub-surface water can be carefully analysed.

**Nose cone**
This steel structure has to bury itself into the surface of the planet or moon so the device can collect valuable samples to return to Earth.

**Tether**
After samples have been collected, the tether will pull the rocket back up and reel it into the ship again using a high tension wire.

SOLAR SYSTEM

# Are the outer planets as stormy as Jupiter?

**William Reid**

An excellent, complicated question! At first glance, Saturn's clouds appear more serene than Jupiter's many vortices, and, of course, its famous Great Red Spot. But there's evidence to suggest that Saturn is just as stormy as Jupiter underneath its outer, yellow haze. Saturn is made of slightly heavier stuff than Jupiter, including ammonia, methane and water, which may create a dense lower layer of activity that is usually shielded from view. But every 20 or 30 years, Saturn erupts in massive storms that circle the entire planet. This last occurred in 2010, with a band of swirling white storms that wrapped around Saturn's northern hemisphere and lasted for months.

It may be that Jupiter's lighter atmosphere can erupt in smaller storms all the time, while the heavier layers of Saturn act as a 'lid' which suppresses surface storms until the pent-up energy is too great and the entire planet goes up in storm. **TM**

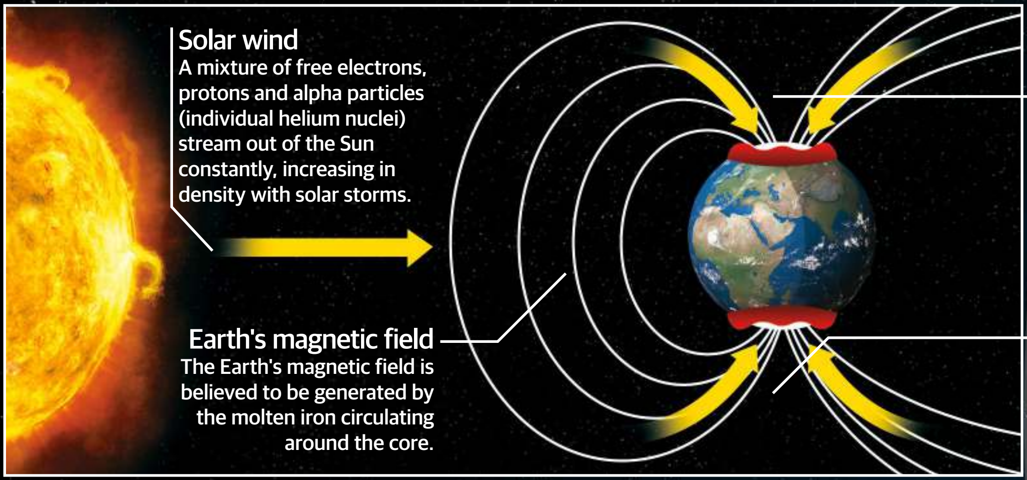
© NASA/JPL-Caltech/2MASS ; NASA/JPL-Caltech/SSI; Adrian Chesterman; Kristian Pikner; KuriousG; NASA, ESA, Hubble Heritage Team

# How are aurorae formed on other planets?

## The Aurora Borealis occurs when the solar wind affects our atmosphere, but this can happen on other worlds, too

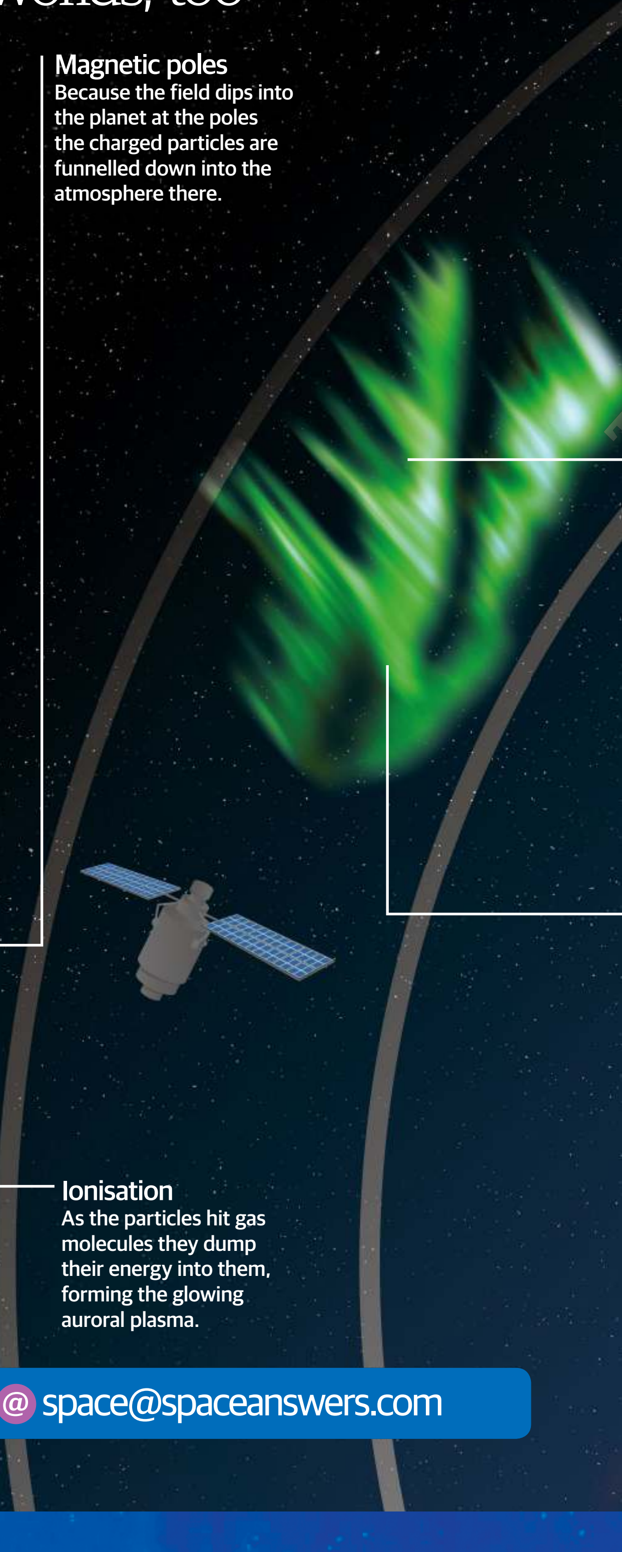
The shimmering northern lights, or Aurora Borealis, are a natural light show that occurs in a loop around the poles. The southern version is known as Aurora Australis. Aurorae occur when charged particles emanating from the Sun (the solar wind) crash into the upper atmosphere: a mixture of electrons, protons and helium nuclei, they lose energy as they collide with atmospheric gas molecules. These gas molecules become ionised - some of their electrons are pulled away, and the gases form a glowing plasma. The gas mix governs the colours we see. Red is generated by low concentrations of oxygen at high altitudes, this changes over to green as oxygen density increases, with blue generated by nitrogen. Pink, yellow and orange have all been observed, presumably due to the layering of different amounts of red, green and blue. Intriguingly, because our eyes construct our colour perception from red, green and blue sensing cells, aurorae could, in principle, form any colour at all, depending on the combination of the primary gas colours. Aurorae are clustered around the poles because the Earth's magnetic field dips into the surface. There, particles are repelled from lower latitudes and funnelled into the atmosphere in loops around both poles. These bands can grow, however, with strong solar storms, occasionally bringing aurora as far south as southern Britain and northern France.

Other planets in the Solar System have varying combinations of magnetic fields and atmospheres, but we have found aurorae there too. The most spectacular display is on Jupiter, with 14-times the magnetic field of Earth. As well as the solar wind it has its moon Io, the most volcanically active body in the Solar System, cutting through its magnetic field while spewing out more gases. Indeed aurorae have been observed around Io, Europa and Ganymede too, because of the complex interactions with Jupiter. Saturn's aurorae have been captured by a number of spacecraft, even from the Hubble Space Telescope in Earth orbit, but the energy characteristics and gases involved produce ultraviolet light that would be invisible to humans. Despite Mars' llimited magnetic field and atmosphere, Martian Aurorae have been observed by the European Mars Express probe, clustered around magnetic variations in the crust. Most curious of all, however, are the Venusian aurorae. Venus has no magnetic field, but Mars Express' Venusian twin found magnetic effects produced by the solar wind interacting with the charged outer layer of the atmosphere. This seems to produce random patches of light, as they are not fixed to magnetic poles. **RH**



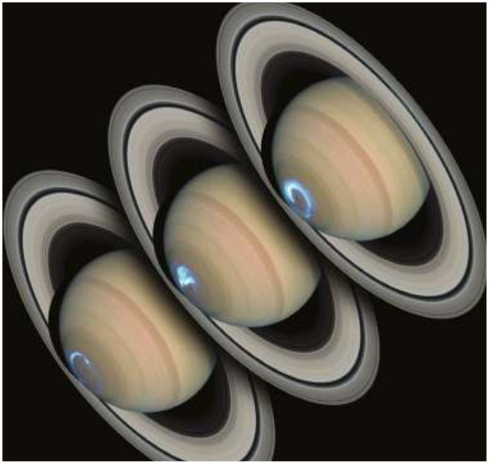
**Solar wind**
A mixture of free electrons, protons and alpha particles (individual helium nuclei) stream out of the Sun constantly, increasing in density with solar storms.

**Earth's magnetic field**
The Earth's magnetic field is believed to be generated by the molten iron circulating around the core.



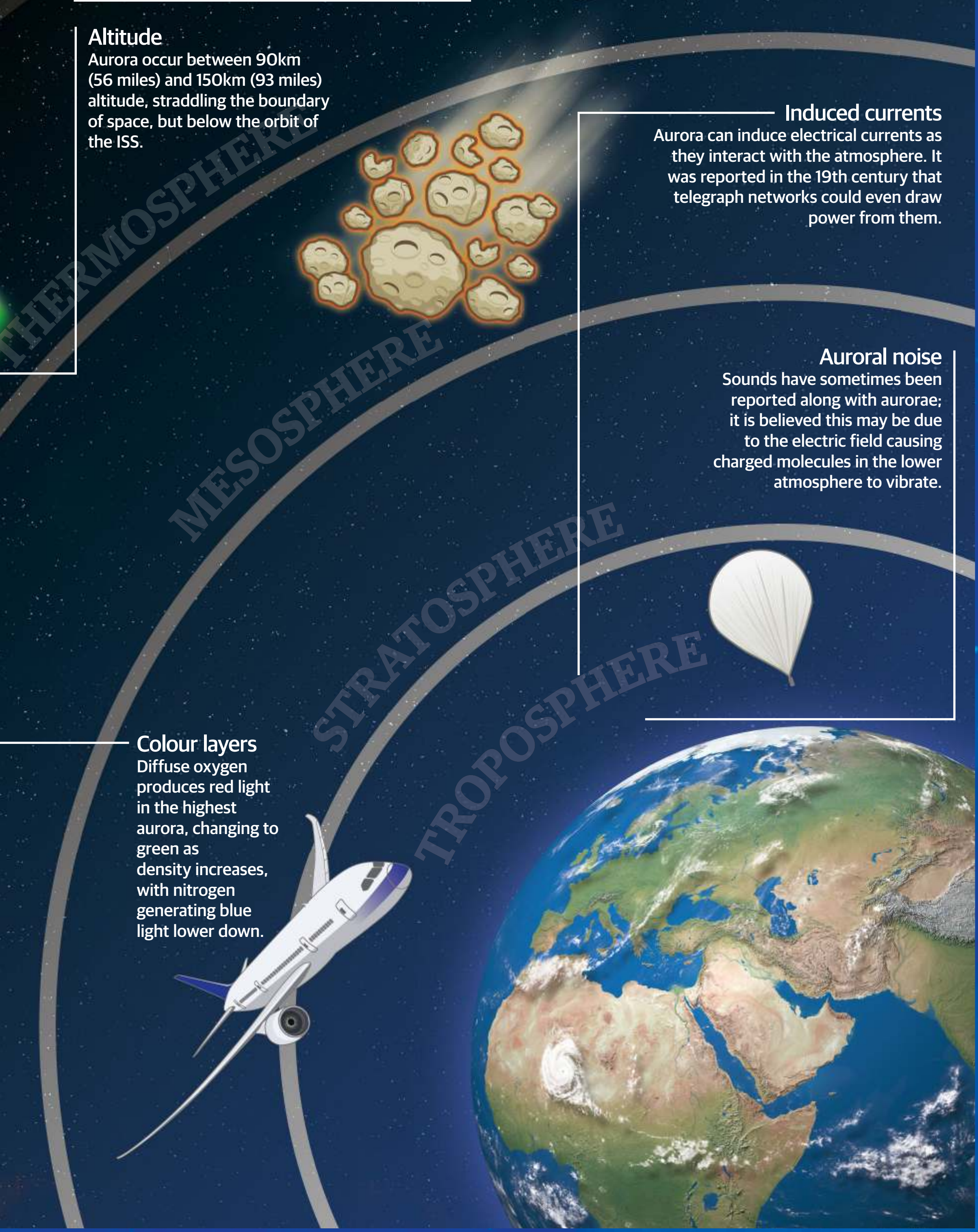
**Magnetic poles**
Because the field dips into the planet at the poles the charged particles are funnelled down into the atmosphere there.

**Ionisation**
As the particles hit gas molecules they dump their energy into them, forming the glowing auroral plasma.



Aurorae at the southern pole of Saturn

© NASA/ESA/J. Clarke (Boston University)



### Altitude

Aurora occur between 90km (56 miles) and 150km (93 miles) altitude, straddling the boundary of space, but below the orbit of the ISS.

### Induced currents

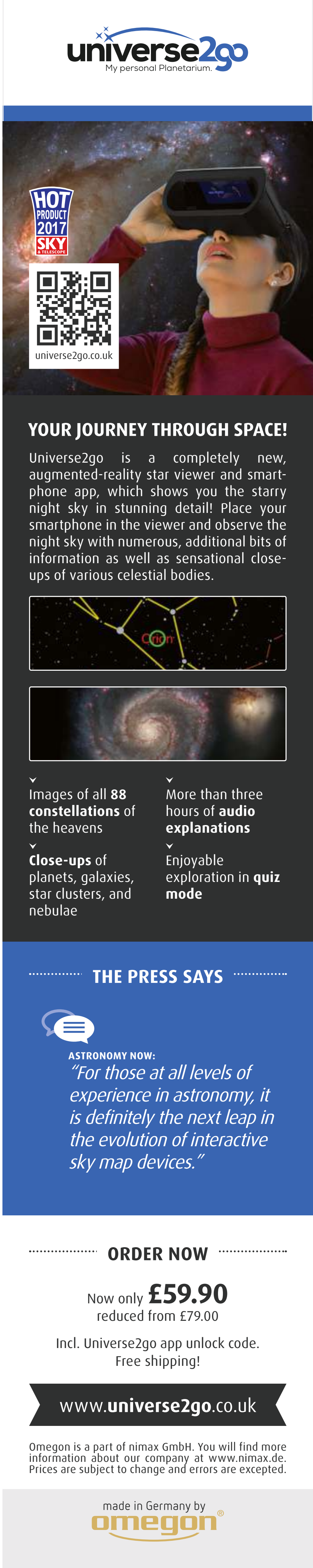
Aurora can induce electrical currents as they interact with the atmosphere. It was reported in the 19th century that telegraph networks could even draw power from them.

### Auroral noise

Sounds have sometimes been reported along with aurorae; it is believed this may be due to the electric field causing charged molecules in the lower atmosphere to vibrate.

### Colour layers

Diffuse oxygen produces red light in the highest aurora, changing to green as density increases, with nitrogen generating blue light lower down.


universe2go
My personal Planetarium.

HOT PRODUCT 2017 SKY & TELESCOPE

universe2go.co.uk

YOUR JOURNEY THROUGH SPACE!

Universe2go is a completely new, augmented-reality star viewer and smartphone app, which shows you the starry night sky in stunning detail! Place your smartphone in the viewer and observe the night sky with numerous, additional bits of information as well as sensational close-ups of various celestial bodies.

- Images of all **88 constellations** of the heavens
- More than three hours of **audio explanations**
- **Close-ups** of planets, galaxies, star clusters, and nebulae
- Enjoyable exploration in **quiz mode**

THE PRESS SAYS

ASTRONOMY NOW:
*"For those at all levels of experience in astronomy, it is definitely the next leap in the evolution of interactive sky map devices."*

ORDER NOW

Now only **£59.90**
reduced from £79.00

Incl. Universe2go app unlock code.
Free shipping!

www.**universe2go**.co.uk

Omegon is a part of nimax GmbH. You will find more information about our company at www.nimax.de. Prices are subject to change and errors are excepted.

made in Germany by
omegon®

# Grand Finale… Why it's not over for Cassini

The spacecraft's final encore at Saturn promises to yield the most exciting science yet!

Written by Luis Villazon

© Tobias Roetsch

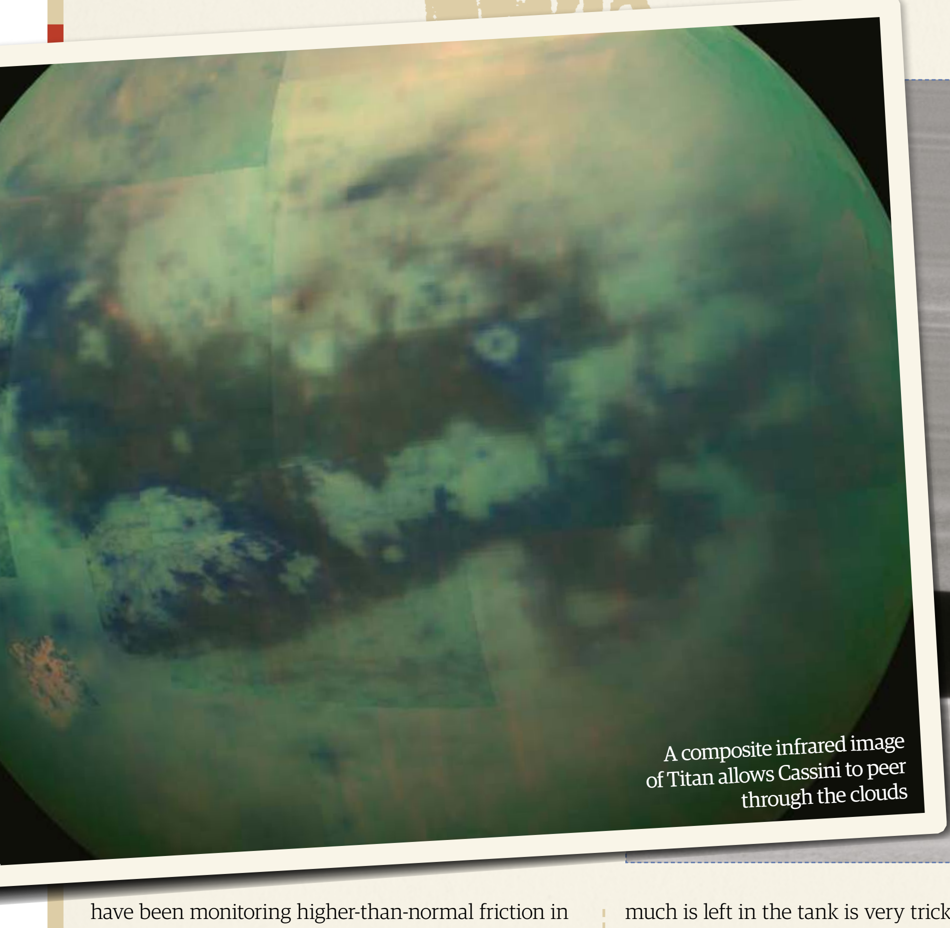
When Cassini reported for duty in 1997, it only signed up for an 11-year tour: seven years to fly to Saturn, then four years of science. But four years got extended to six, then 13, and now its final mission promises to be its most spectacular. On 15 September, Cassini will dive-bomb into Saturn's upper atmosphere at 123,000 kilometres (76,429 miles) an hour and be incinerated. But why does Cassini need to be destroyed? Why not just leave it in orbit to collect data forever? Because, after 20 years in space, Cassini is wearing out.

Although the plutonium-238 in the radioisotope thermoelectric generators could supply it with electrical power for another decade or more, several other key systems will not last that long. To point the spacecraft in the correct direction for the science instruments, and to aim the hi-gain antenna back towards Earth, Cassini uses three electrical reaction wheels (one for each axis). These wheels have accumulated more than 10 billion revolutions each, and the bearings are starting to degrade. Wheel three failed briefly back in 2003, and mission controllers

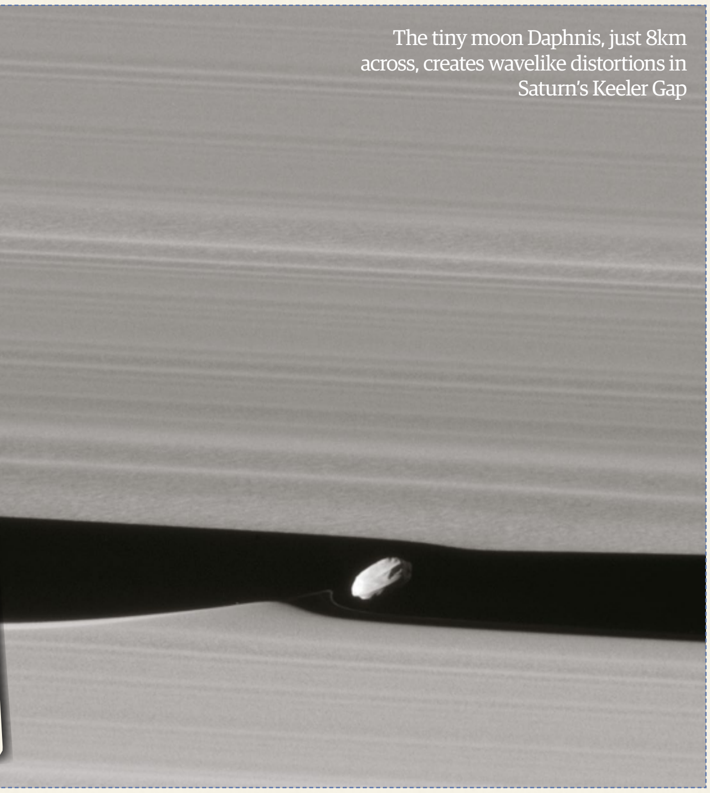
**“The antenna was the Italian bodyguard of the mission"**

As well as providing communications, the hi-gain antenna (HGA) was originally designed to protect Cassini from dust impacts during the Saturn Orbit Insertion. “The SOI was perfectly executed and the antenna did not suffer any degradation from impacts, so I was only moderately worried for the first close-passes [of the Grand Finale].”

**ENRICO FLAMINI,**
**ASI PROGRAMME MANAGER FOR CASSINI**



A composite infrared image of Titan allows Cassini to peer through the clouds



The tiny moon Daphnis, just 8km across, creates wavelike distortions in Saturn's Keeler Gap

have been monitoring higher-than-normal friction in the bearings of the others since then. If one wheel fails, Cassini has a spare that can be rotated to match the axis of any of the other three, but if two wheels fail at once, the only way to turn the spacecraft is to use the attitude control jets. These hydrazine thrusters aren't just there as an emergency backup; they are used routinely to hold Cassini steady during orbital manoeuvres where the reaction wheels wouldn't be powerful enough. They are also needed to absorb the momentum of the reaction wheels when they reach their maximum speed in any one direction and need to be reset. For more than a decade, the Cassini team has been very carefully managing the use of the reaction wheels to reduce wear on the bearings and conserve hydrazine fuel for the thrusters, but even so, supplies are running low.

Even more critical is the fuel for Cassini's main engine. This uses bipropellant (monomethyl hydrazine and nitrogen tetroxide, which burn spontaneously when mixed) and estimating how much is left in the tank is very tricky. Todd Barber is the lead propulsion engineer for the Cassini mission. "There is no gas gauge on the mission," he explains, "I'm the gas gauge! I can tell you we have only one per cent of the bipropellant left - plus or minus two per cent!".

Without fuel and oxidiser for the main engine, the spacecraft wouldn't be able to adjust its own trajectory. Leaving it in its current orbit isn't an option. The chaotic gravitational tugs from all of Saturn's moons would eventually pull Cassini off course and risk it crashing onto Enceladus or Titan. While that might once have been considered a perfectly worthwhile mission in its own right, it is now considered unacceptable - because of data gathered by Cassini itself.

The identification of likely subsurface water on Titan and Enceladus, and rich organic molecules on their surfaces, makes them prime candidates in the search for extraterrestrial life. If Cassini were to crash on either of these moons, there is a chance that bacterial spores hitchhiking in some deep crevice might contaminate these pristine worlds. Not only could this wreak havoc on any ecosystem there, it would make it impossible for scientists to know for sure whether any life we might one day find there is a native species, or just an invader from Earth. In a sense, Cassini is a victim of its own success. The scientific discoveries it made about Titan and Enceladus prohibit it from ever visiting them.

"We did look at a number of possible endings for Cassini," says Barber, "including escaping the Saturn system (perhaps for another planetary target), parking in a safe survey orbit at Saturn, or crashing into one of Saturn's [other] moons." In the end, the team decided however, that it would take too long to get anywhere else interesting outside of the Saturn system. A survey orbit wouldn't yield as much science, and most importantly, impacting Saturn was the only sure way to sterilise the spacecraft.

So in December 2016, the main engine was fired for the 183rd, and last, planned burn, pushing Cassini into a new orbit that rises high above Saturn's north pole and then dives down towards the planet. But this isn't just a suicide leap. Cassini is aiming for the gap between the innermost ring and Saturn itself. Dubbed Cassini's Grand Finale, these orbits will make 22 passes inside of the rings before plunging into Saturn's atmosphere. This is completely uncharted territory; no other spacecraft has ever been in a position to fly this close to Saturn, and the science return will be unprecedented. But, it's also an extremely dangerous manoeuvre that could only be entertained right at the end of Cassini's career, when mission planners can afford to take more risks. The rocks that make up the main rings can range from microscopic, all the way to the size of a mountain. At the extremely high relative velocities involved, even something the size of a pea could completely destroy the spacecraft. Professor Michele Dougherty is the principle investigator in charge of the magnetometer experiment on Cassini, and she says that the first of

## "My kingdom for a gas gauge!"

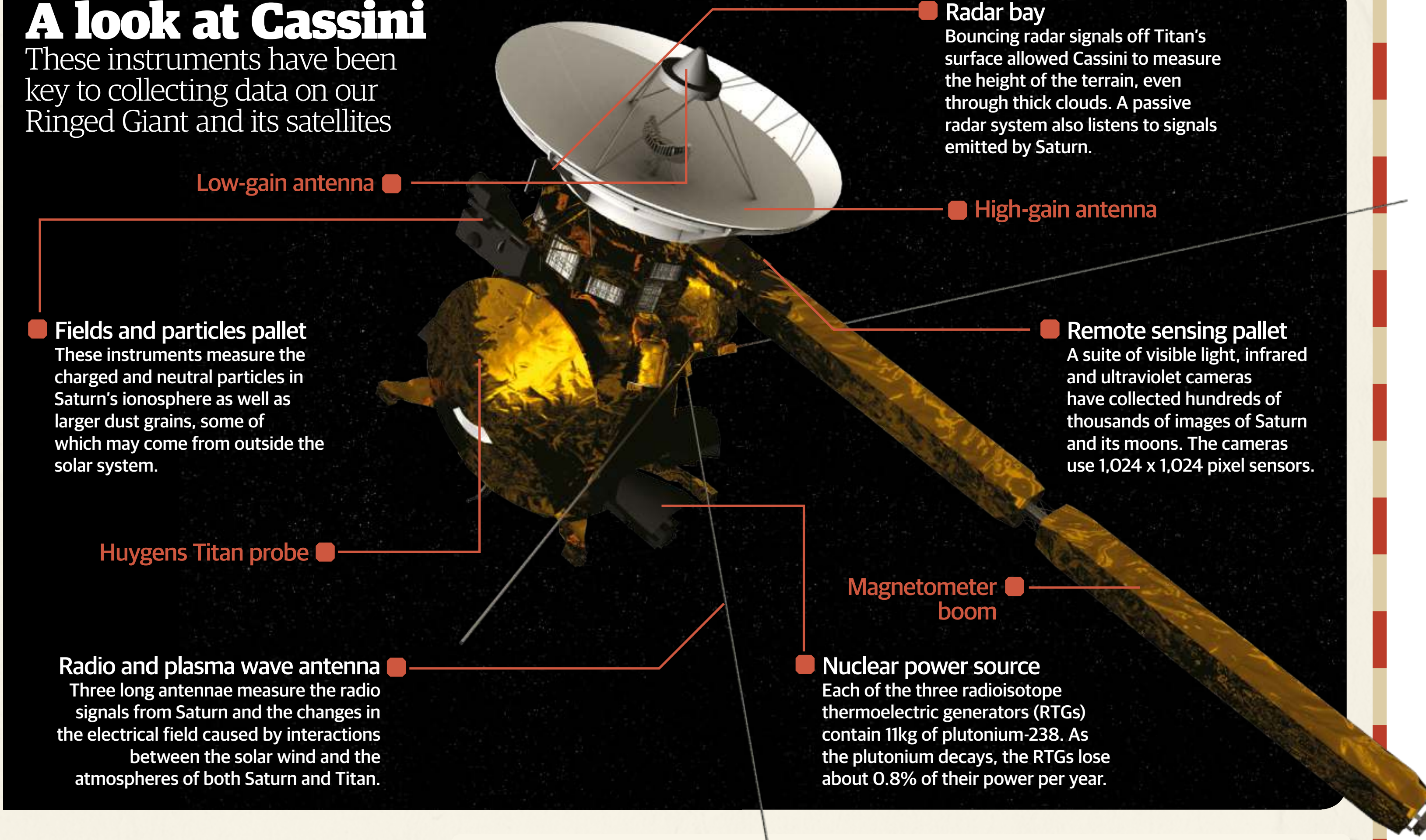
The Cassini team were only able to estimate the amount of fuel remaining using indirect calculations. "Incorporating flowmeters in the propulsion feed lines [on future missions] could reduce our error substantially so we would really know how much propellant remains. This would have saved years of worrying about bipropellant depletion."

**TODD BARBER,**
**LEAD PROPULSION ENGINEER**

> "We did look at a number of possible endings for Cassini, including escaping the Saturn system" **Todd Barber**

# A look at Cassini

These instruments have been key to collecting data on our Ringed Giant and its satellites



**Radar bay**
Bouncing radar signals off Titan's surface allowed Cassini to measure the height of the terrain, even through thick clouds. A passive radar system also listens to signals emitted by Saturn.

**Fields and particles pallet**
These instruments measure the charged and neutral particles in Saturn's ionosphere as well as larger dust grains, some of which may come from outside the solar system.

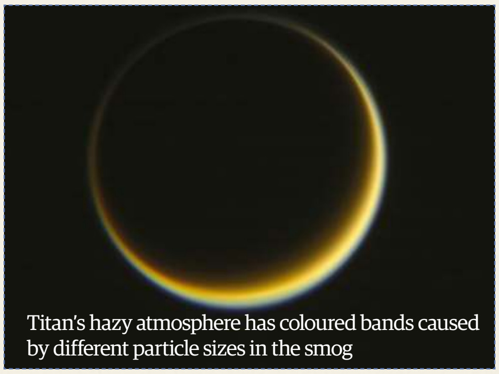
**Remote sensing pallet**
A suite of visible light, infrared and ultraviolet cameras have collected hundreds of thousands of images of Saturn and its moons. The cameras use 1,024 x 1,024 pixel sensors.

**Radio and plasma wave antenna**
Three long antennae measure the radio signals from Saturn and the changes in the electrical field caused by interactions between the solar wind and the atmospheres of both Saturn and Titan.

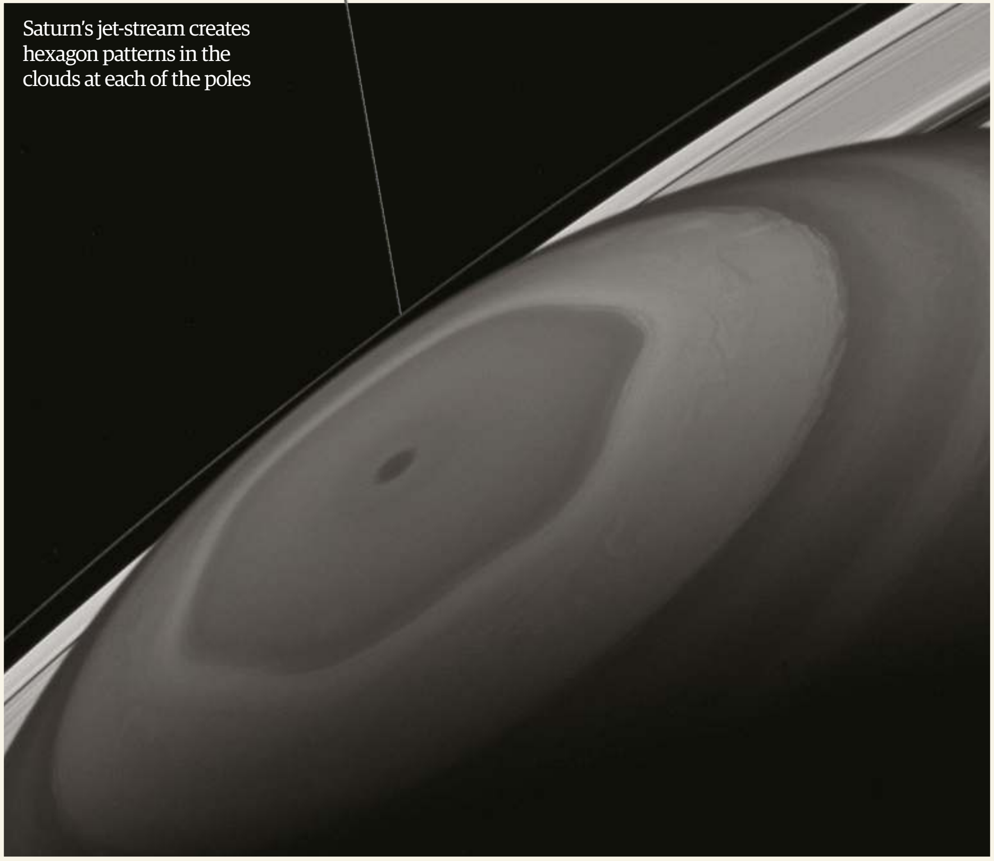
**Nuclear power source**
Each of the three radioisotope thermoelectric generators (RTGs) contain 11kg of plutonium-238. As the plutonium decays, the RTGs lose about 0.8% of their power per year.

## "Enceladus is a top candidate for finding life"

"What we know from the composition of [Enceladus'] ocean is based on the direct sampling of the plumes. The main component is water [but] we have also observed that the ice particles… contain salts [and other organic precursors]. This type of environment is known within deep oceans on Earth to harbour forms of life."
**NICOLAS ALTOBELLI, CASSINI PROJECT SCIENTIST AT ESA**



Titan's hazy atmosphere has coloured bands caused by different particle sizes in the smog

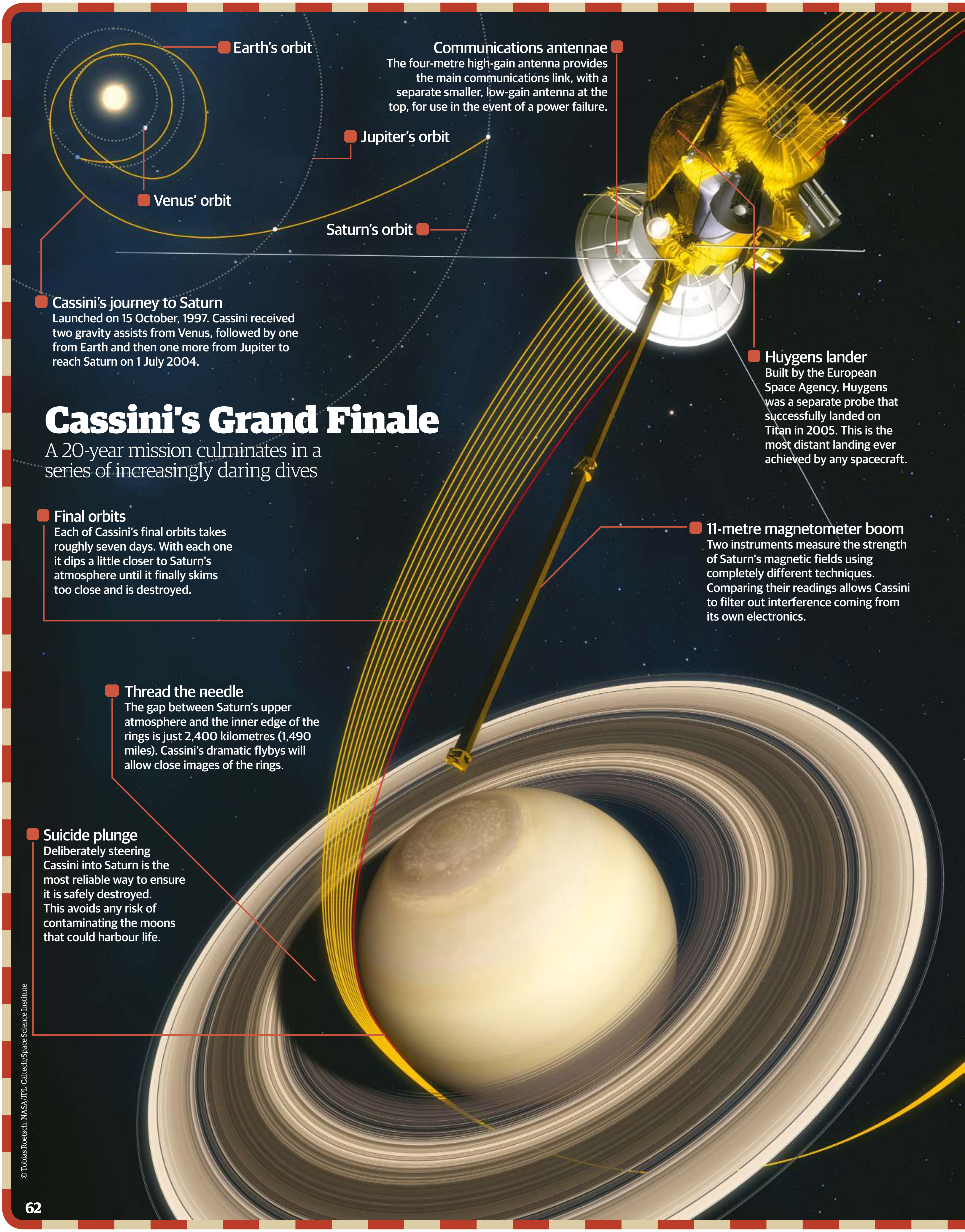


Saturn's jet-stream creates hexagon patterns in the clouds at each of the poles

© Adrain Mann; NASA/JPL/University of Arizona/University of Idaho; NASA/JPL-Caltech/Space Science Institute

# Cassini's Grand Finale

A 20-year mission culminates in a series of increasingly daring dives



**Communications antennae**
The four-metre high-gain antenna provides the main communications link, with a separate smaller, low-gain antenna at the top, for use in the event of a power failure.

**Cassini's journey to Saturn**
Launched on 15 October, 1997. Cassini received two gravity assists from Venus, followed by one from Earth and then one more from Jupiter to reach Saturn on 1 July 2004.

**Huygens lander**
Built by the European Space Agency, Huygens was a separate probe that successfully landed on Titan in 2005. This is the most distant landing ever achieved by any spacecraft.

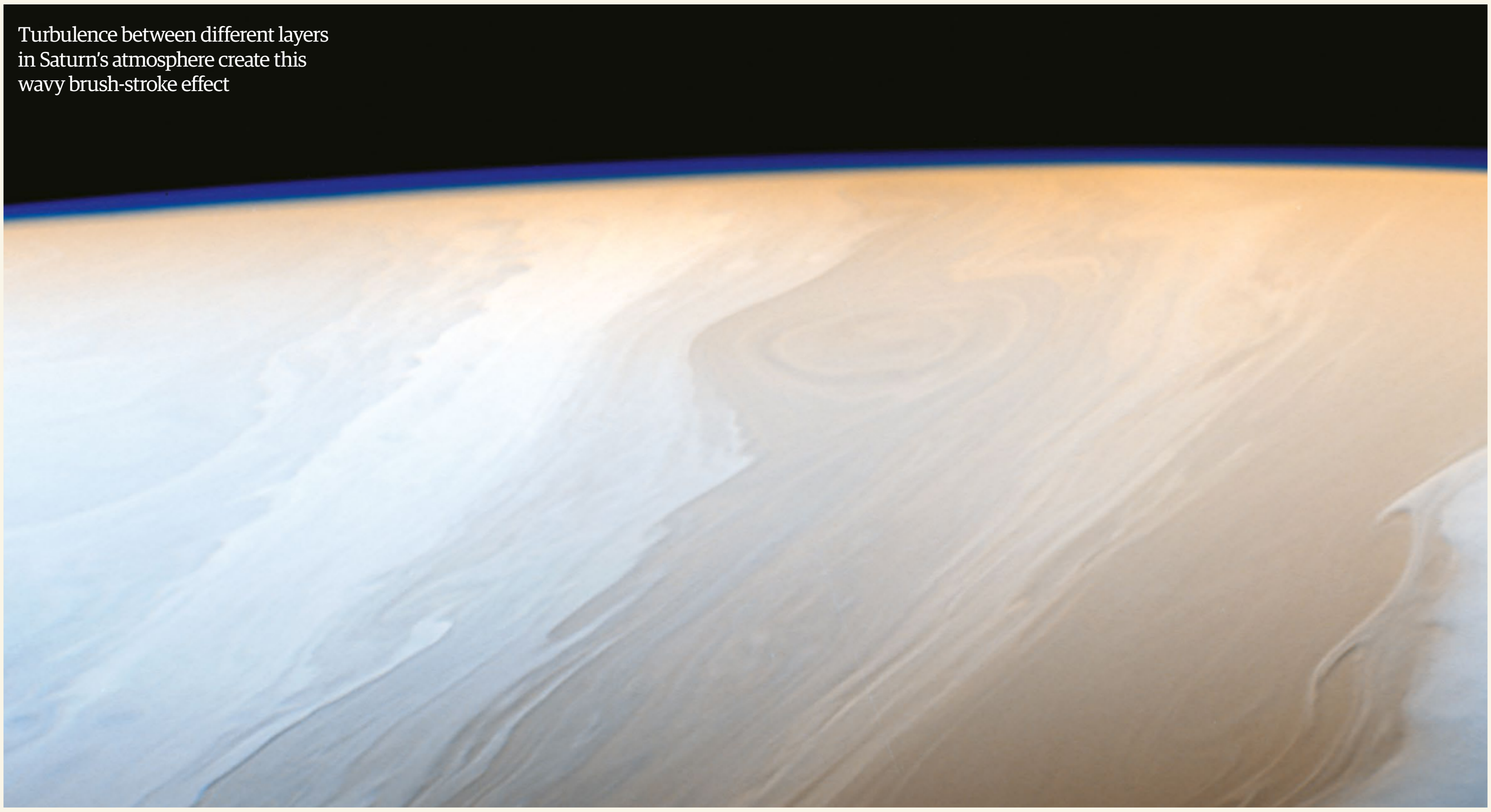
**Final orbits**
Each of Cassini's final orbits takes roughly seven days. With each one it dips a little closer to Saturn's atmosphere until it finally skims too close and is destroyed.

**11-metre magnetometer boom**
Two instruments measure the strength of Saturn's magnetic fields using completely different techniques. Comparing their readings allows Cassini to filter out interference coming from its own electronics.

**Thread the needle**
The gap between Saturn's upper atmosphere and the inner edge of the rings is just 2,400 kilometres (1,490 miles). Cassini's dramatic flybys will allow close images of the rings.

**Suicide plunge**
Deliberately steering Cassini into Saturn is the most reliable way to ensure it is safely destroyed. This avoids any risk of contaminating the moons that could harbour life.

© Tobias Roetsch; NASA/JPL-Caltech/Space Science Institute



Turbulence between different layers in Saturn's atmosphere create this wavy brush-stroke effect

the Grand Finale orbits was her most nerve-wracking moment of the entire 20-year mission. "The hi-gain antenna was pointed towards the direction of travel to shield the spacecraft against impacts with dust particles," she explains, "but our magnetometer boom sticks out way beyond the hi-gain." Even a single dust mote could have destroyed the magnetometer and deprived Professor Dougherty of any data about Saturn's magnetic field. "I must admit I had a few sleepless nights over that first orbit. Fortunately for us, it seems that the gap [between Saturn and the rings] is much emptier than we thought."

It looks as if the reason for this emptiness is precisely down to Saturn's weird magnetic field. Dr Luke Moore uses Cassini to study Saturn's upper atmosphere. "Whereas Jupiter's powerful magnetic field sweeps up roughly one ton per second of sulphur-dioxide released from its volcanic moon, Io," he explains, "Saturn's magnetic field is weaker, and significantly less water vapour escapes its cryovolcanic moon, Enceladus." This creates a much thinner halo of plasma around Saturn. But it is also something of a scientific puzzle, since current theories of planetary magnetism can't explain why Saturn's field should be so weak.

Cassini completed its first journey through the plane of the rings on 26 April this year. At the time of writing it has survived another 18 orbits and the most recent one, on 14 August, added yet a new danger to the mix. On each successive orbit, Cassini has been spiralling ever inwards, and the final five orbits will actually dip into Saturn's upper atmosphere. Cassini's reaction wheels aren't strong enough to keep the spacecraft pointed correctly as it is buffeted by the atmosphere, so it must use its hydrazine thrusters to compensate. But there is still the danger that Saturn's atmosphere is thicker or extends further than scientists thought, which could swallow the spacecraft up prematurely. "We have planned for that contingency, though," says Barber, "by allowing a pop-up manoeuvre to get us out of the atmosphere for subsequent passages. I'm pleased to report that we cancelled Orbit Trim Manoeuvre 473 - the pop-up manoeuvre - just a couple of days ago, so this bodes well [for the other orbits]." In fact, Cassini's scientists are feeling sufficiently bold that they have even planned for a possible pop-down manoeuvre, in case Saturn's atmosphere turns out not to be dense enough for them to gather all the data they need.

Predicting the exact moment of Cassini's demise, once it makes the final plunge, isn't easy. One of the key measurements that the spacecraft will make is the extent and density of the very atmosphere that will destroy it. But Preston Dyches, head of Science Communication, thinks it will be over very quickly. "Cassini will be able to keep its antenna pointed

"This is completely uncharted territory; no other spacecraft has ever been in a position to fly this close to Saturn"

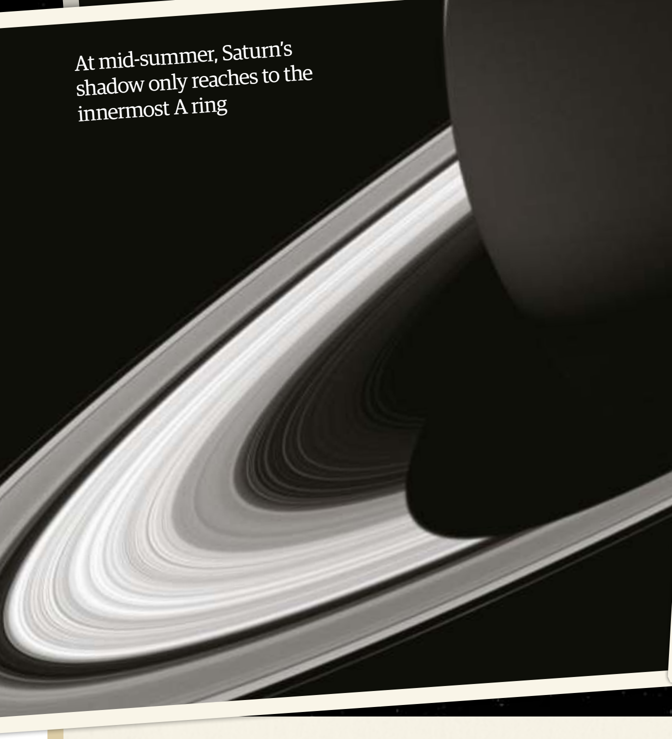
**"Saturn's internal magnetic field is the real surprise here"**

Current theories do not explain Saturn's weird magnetic field. "We might need to change our theory of planetary dynamos. Some people have suggested that Saturn's magnetic field might be decaying, but I don't know what the answer is yet. I hope within a year we will know a lot more."

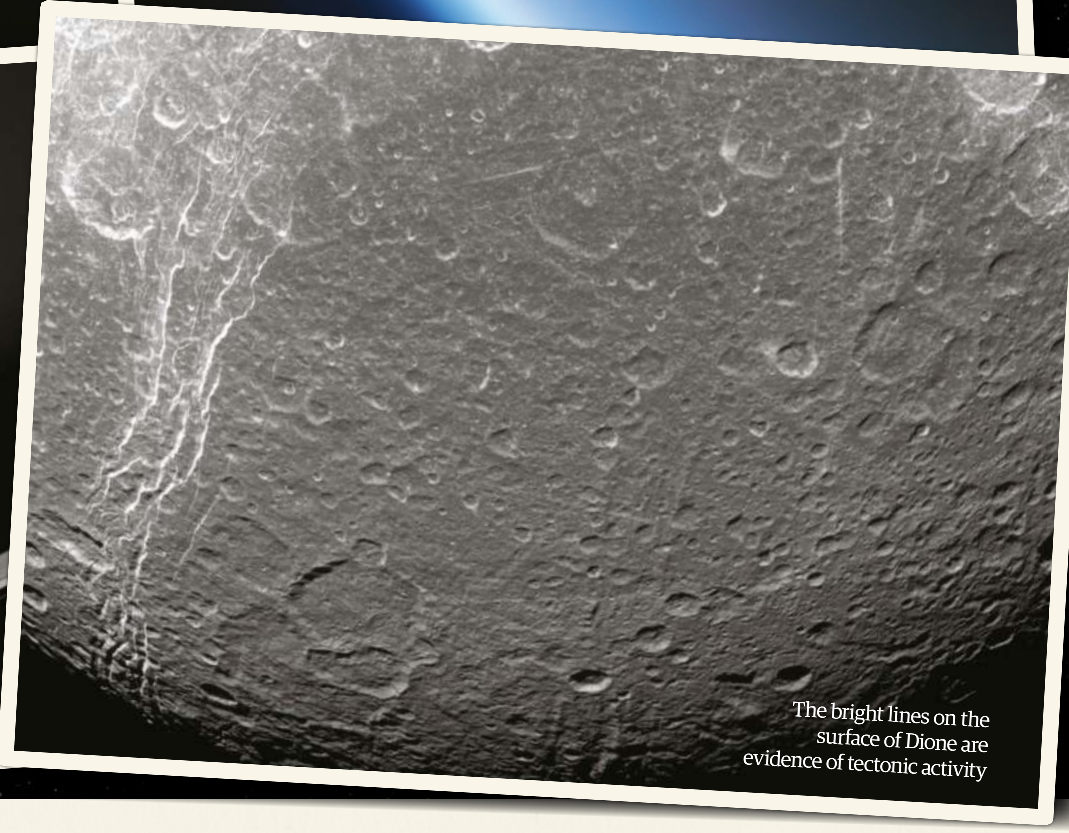
**PROFESSOR MICHELE DOUGHERTY, PRINCIPAL INVESTIGATOR FOR CASSINI'S MAGNETOMETER**

Cassini flew within 41,000km of Pandora to take this high resolution image

Sunlight glints off a hydrocarbon lake on Titan. The faint pink colour may be waves



At mid-summer, Saturn's shadow only reaches to the innermost A ring



The bright lines on the surface of Dione are evidence of tectonic activity

toward Earth for one to two minutes after entry into Saturn's atmosphere," he says. "Once the atmosphere is denser than the thrusters can compensate for, the spacecraft will begin to tumble and the radio link with Earth will be permanently severed. The spacecraft will break apart and burn up like a meteor within a couple of minutes after losing contact." That loss of signal is expected to happen about 1,500 kilometres (932 miles) above Saturn's cloud tops. That sounds like a long way up still, but by then the atmospheric pressure will already be equivalent to the pressure on Earth at sea level.

In that final couple of minutes, all seven of the magnetosphere and plasma science instruments will be furiously collecting data. The most important observations will come from the Ion and Neutral Mass Spectrometer, or INMS. "The instrument will directly sample the composition and structure of the atmosphere, which cannot be done from orbit," says Dyches. "The spacecraft will be oriented so that INMS (which is on the side of the spacecraft where the Huygens probe was attached) is pointed in the direction of motion, to allow it the best possible access to oncoming atmospheric gases."

The end of Cassini, isn't the end of Cassini's science though. It will take at least another year to analyse the data just from the Grand Finale alone. But, Professor Enrico Flamini, Cassini's programme manager at the Italian Space Agency, ASI, believes that the data Cassini has gathered will feed generations of scientists. "One of the major achievements has been the discovery of the astrobiological potential of Titan and Enceladus. Now the question is: are there life forms?" According to Professor Dougherty, the success of Cassini has also encouraged ESA to back other deep space missions, such as the Jupiter Icy Moons Explorer (JUICE).

"Cassini really gave ESA the confidence that we can do worthwhile science at the outer planets, and I don't think it's an exaggeration to say that Cassini enabled JUICE." Jonathan Fortney, a scientist with the Cassini team, thinks that the mission will even provide insights about planets outside our solar system. "Just like studying the Sun in as much detail as possible helps us to understand stars as a class," he says. "Jupiter and Saturn don't have the same composition as the Sun, even though all three are made of hydrogen and helium. We're just beginning to be able see if that is true for exoplanets, compared to their stars."

Saturn's year is almost 30-Earth-years long, so in the time it has been there, Cassini has seen the planet change from being illuminated from below, to above the rings. The sheer length of its mission has allowed scientists to observe how Saturn's atmosphere varies, not just from place to place on the planet, but also over time. "Many discoveries made by Cassini were directly linked to different seasons," says Nicolas Altobelli, programme manager for Cassini at ESA. When Cassini arrived in 2004, it was late winter in Saturn's northern hemisphere. It is now mid-summer, and it looks like the data it has collected will keep bringing surprises for several seasons to come.

> "Cassini's scientists are feeling sufficiently bold that they have even planned for a possible pop-down manoeuvre"

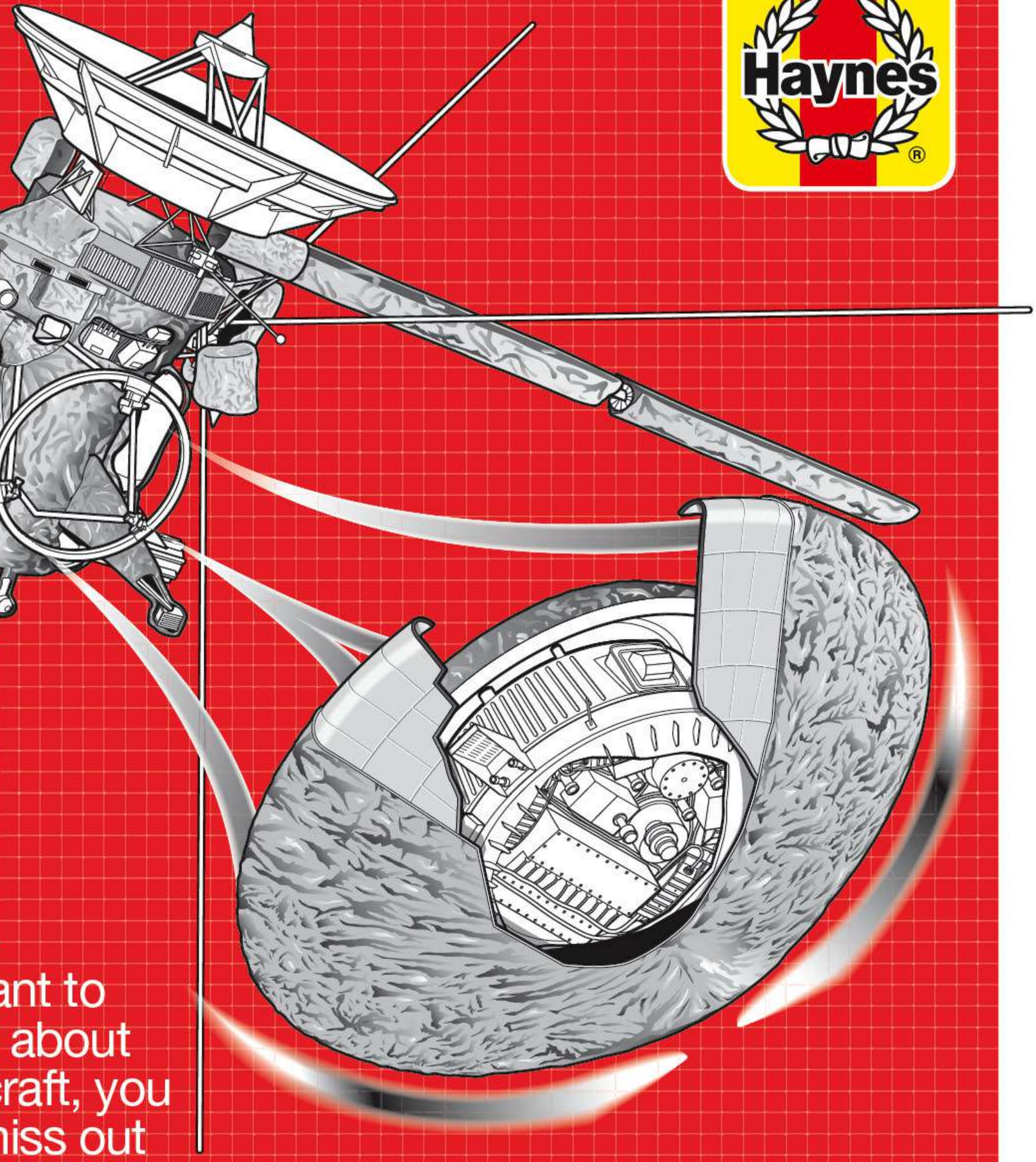
**"It revolutionises our understanding of Saturn's atmosphere"**

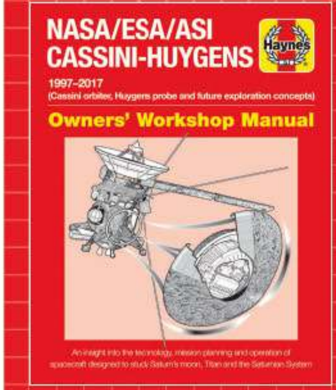
"Portions of Saturn's atmosphere are hidden from Earth-based telescopes. Cassini has allowed us to study spatial and temporal variabilities. Prior to Cassini there were only three fly-by spacecraft missions, which, while successful in their own right, are unsuited for firmly constraining the space environment of a giant planet."

**LUKE MOORE, PARTICIPATING SCIENTIST WITH THE CASSINI PLANETARY ATMOSPHERE TEAM**

© NASA/JPL/University of Idaho; NASA/JPL-Caltech/Space Science Institute; NASA/JPL/University of Arizona/University of Idaho

# Discover more about NASA's incredible Cassini spacecraft

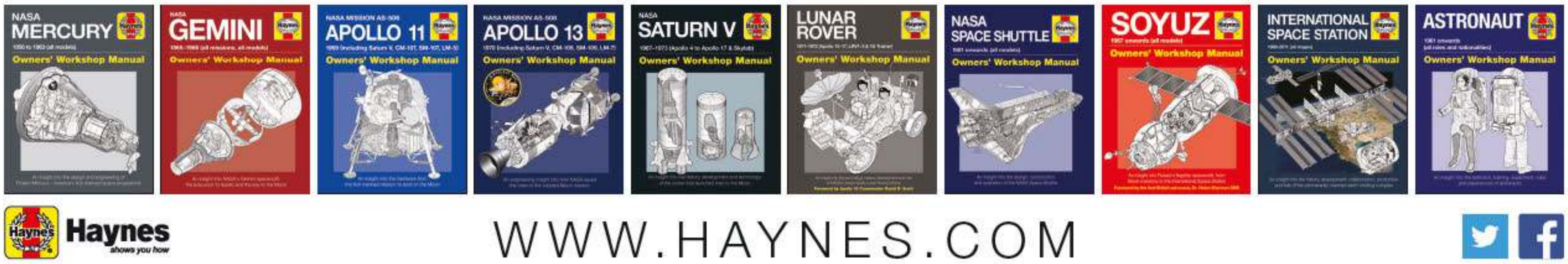




NASA/ESA/ASI
CASSINI-HUYGENS
1997–2017
(Cassini orbiter, Huygens probe and future exploration concepts)
Owners' Workshop Manual

An insight into the technology, mission planning and operation of spacecraft designed to study Saturn's moon, Titan and the Saturnian System

> “If you want to know more about this spacecraft, you shouldn't miss out on this book”
>
> **GF WILLMETTS, SFCROWSNEST**



NASA MERCURY
1959 to 1963 (all models)
Owners' Workshop Manual

NASA GEMINI
1965–1966 (all missions, all models)
Owners' Workshop Manual

NASA MISSION AS-506 APOLLO 11
1969 (including Saturn V, CM-107, SM-107, LM-5)
Owners' Workshop Manual

NASA MISSION AS-508 APOLLO 13
1970 (including Saturn V, CM-109, SM-109, LM-7)
Owners' Workshop Manual

NASA SATURN V
1967–1973 (Apollo 4 to Apollo 17 & Skylab)
Owners' Workshop Manual

LUNAR ROVER
Owners' Workshop Manual

NASA SPACE SHUTTLE
1981 onwards (all models)
Owners' Workshop Manual

SOYUZ
1967 onwards (all models)
Owners' Workshop Manual

INTERNATIONAL SPACE STATION
Owners' Workshop Manual

ASTRONAUT
1961 onwards
(all roles and nationalities)
Owners' Workshop Manual

Haynes
shows you how

WWW.HAYNES.COM

# SPACEX... WE HAVE A PROBLEM!

## The private space company's CEO Elon Musk recently announced that the Falcon Heavy might not even reach its orbit on its maiden launch

On 19 July 2017, Elon Musk attended the International Space Station Research and Development (ISSR&D) conference in Washington D.C., United States. At the meeting, Musk was asked a question concerning the risk of launching the first Falcon Heavy rocket, to which he responded by lowering the expectations of the Falcon Heavy launch. The entrepreneur claimed that there is a "real good chance" it will not reach its orbit. In fact, Musk even went as far as to say, "I hope it makes it far enough away from the pad that it does not cause pad damage. I would consider even that a win, to be honest."

The Falcon Heavy consists of a reinforced Falcon 9 core, which will carry the main payload and the second-stage Merlin rocket. The first stage of Falcon Heavy is an engineering concept that involves much complexity and innovation. It includes two Falcon 9 strap-on boosters attached to the main core. Combined for the first stage, this will behold 27 engines producing over 22,000 kiloNewtons of thrust power, which is almost equivalent to eighteen Boeing 747 aircraft. This has the power to take almost 55 metric tonnes of payload into a Low Earth Orbit (LEO), only Apollo's Saturn V is capable of carrying more payload mass.

Originally, Elon Musk was targeting the first-time launch of the revolutionary, reusable Falcon Heavy in 2013. Since then, there has been an array of setbacks, and Musk admitted, "It actually ended up being way, way harder to do Falcon Heavy than we [first] thought." This is predominantly due to the fact that when you combine the three Falcon 9 rockets together, it adds an abundance of complications that need to be tested and accounted for. "At first, it sounds really easy: just stick two first stages on as strap-on boosters. How hard can that be?" Musk said. "But then everything changes. All the loads change, aerodynamics totally change, you've tripled the vibration and acoustics." He goes on to explain, "The amount of load you're putting through that centre core is crazy, because you've got two super-powerful boosters also shoving that centre core, so we had to redesign the whole centre core airframe."

While discussing these aspects, Musk also emphasised how extremely difficult it is to test these issues on the ground.

Despite these points, his enthusiasm and clear faith in the project were not silenced. As he humorously told the audience, "I encourage people to come down to the Cape to see the first Falcon Heavy mission. It's guaranteed to be exciting."

### Falcon 9

The Falcon 9 has been launched 38 times over seven years, with a success rate of 95 per cent. These launches include resupplies from NASA to the ISS, which is a testament to its reputation. This two-stage rocket mainly consists of nine Merlin engines transporting its main payload.

### Falcon Heavy

The launch of the first Falcon Heavy is planned to happen before the end of 2017. This would make it the second most powerful rocket in history, behind Apollo's Saturn V.

| Falcon 9 | | Falcon Heavy |
|---|---|---|
| 549,054 kilograms<br>(1,207,920 pounds) | **Mass** | 1,420,788 kilograms<br>(3,125,735 pounds) |
| 70 metres<br>(230 feet) | **Height** | 70 metres<br>(230 feet) |
| $62,000,000<br>(£48,000,000) | **Cost*** | $90,000,000<br>(£69,000,000) |
| 22,800 kilograms<br>(50,265 pounds) | **Payload to LEO** | 63,800 kilograms<br>(140,660 pounds) |
| Stage 1 = 7,607 kiloNewtons (sea level)<br>Stage 2 = 934 kiloNewtons | **Thrust** | Stage 1 = 22,819 kiloNewtons (sea level)<br>Stage 2 = 934 kiloNewtons |
| 3.7 kilometres (12 feet) | **Diameter** | 12 metres (40 feet) |

*per launch

SpaceX intends to certify the Falcon 9 to be human-rated for transporting NASA astronauts to the ISS

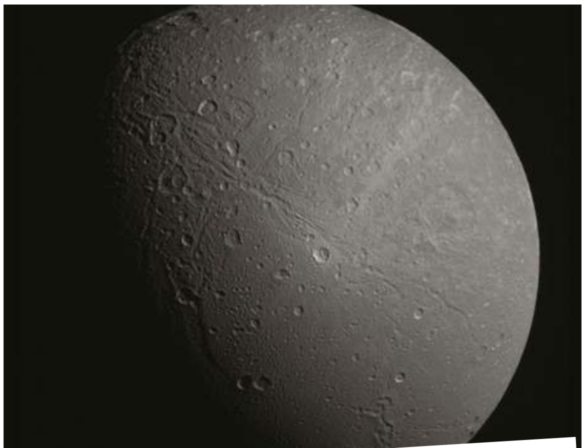
> “I encourage people to come down to the Cape to see the first Falcon Heavy mission. It’s guaranteed to be exciting”
>
> **Elon Musk**

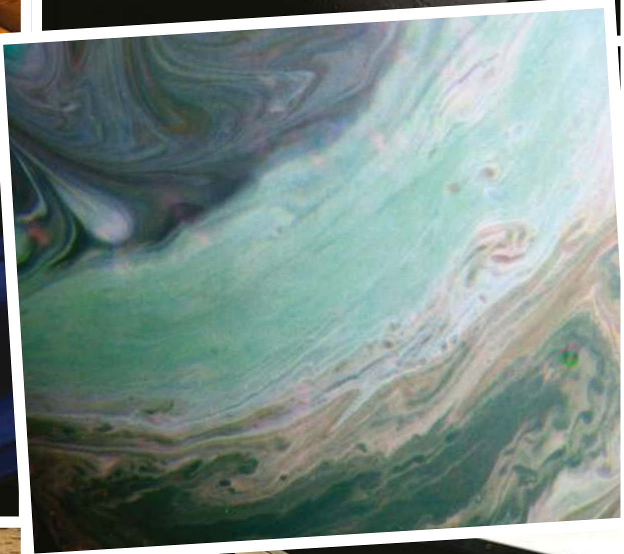
© SpaceX / Alamy Stock Photo: Adrian Mann

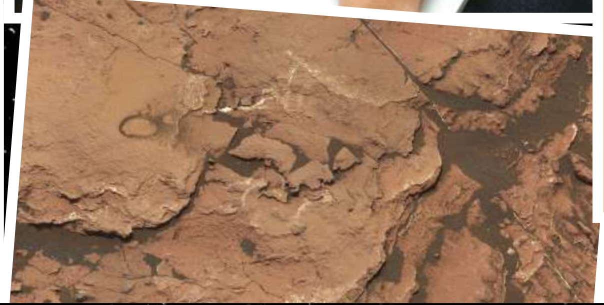
# Create images from Spacecraft Data

Space agencies need you! Learn how you can get involved in processing images – and contribute to space science

Written by
Stuart Atkinson







# IAN REGAN

**Ian Regan is currently working part-time as a digital artist for the forthcoming big-screen film, *In Saturn's Rings*: a ground-breaking visual feast which will take the viewer on a journey around the Solar System using only real photographic data. He is chiefly responsible for the segment where the viewer flies over the varied and Earth-like surface of Titan (Saturn's largest moon). His favourite mission is the Cassini-Huygens orbiter. "As far as targets are concerned, the Saturn system is hard to beat."**

**How did you get started in processing images taken by space missions?**

In 1988, at just six years of age, my lifelong interest in astronomy was sparked after I stumbled across a double-page schematic of the Solar System in my mother's deluxe *Reader's Digest* world atlas. Not long afterwards, the Voyager 2 encounter with Neptune in 1989 offered my first opportunity to experience a major space event unfolding before my eyes. I can vividly recall scanning the newspaper every day, looking for any pictures or articles I could add to my scrapbook. I also kept an eagle eye on the evening TV news bulletins, hoping to record any reports on the flyby with the family's brand-new VCR.

**Cassini has obviously been a major inspiration?**

Yes. By the time Cassini successfully burned its main engine to enter orbit around Saturn, the internet had completely changed the way I practised my hobby: I now had access to raw data only hours after it had been taken and beamed back to Earth. Online forums, including the venerable **unmannedspaceflight.com** (founded by Doug Ellison), cemented my interest in image processing, and I began to produce my first black-and-white Cassini mosaics of Saturn.

**Out of all the images you've processed which is your favourite?**

The image I processed earlier this year is probably my favourite and most satisfying. In the early hours of 13 April 2017, Cassini was coasting through Saturn's shadow when it captured a mammoth mosaic of the planet as seen from that vantage point. The final colour image constitutes of 96 monochromic photos, spread across a four by eight grid of stacked red, green and blue filtered frames. The reason I'm most proud of this image is down to its sheer scale and complexity: Cassini took four hours to capture the frames I assembled, and in that time, the scene changed just enough to make the project challenging. Also, some high-resolution data was missing, and I had to improvise using lower quality to fill those gaps.

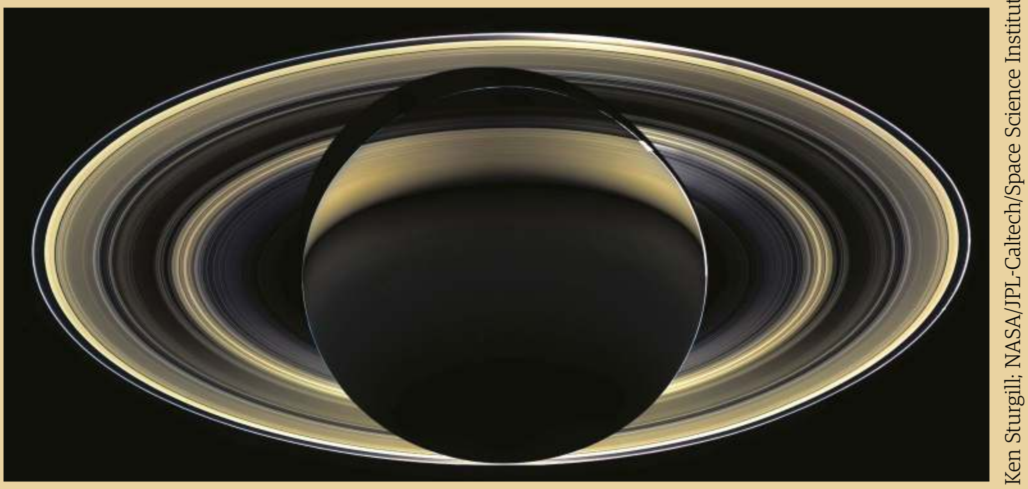
**Tell us a little about the hardware, software and processes you use in your work...**

Unlike the vast majority of other processors, I don't use Photoshop. I have been a loyal user of Paint Shop Pro since 1994, when I installed a shareware copy from a floppy disk onto my 486 PC.

Over the years, I have upgraded from one new incarnation to the next. The first monochrome mosaics I threw together were produced in Version 8, while the Saturn 'Grand Finale' mosaic I mentioned earlier was processed using X6. I also use ImageJ (great for working in 32-bit mode), and the latest version of Affinity for Windows.

**What do you personally get out of all this hard work processing images? Why do you do it when NASA/ESA and others produce so many high-quality images of their own?**

The sheer volume of data collected by the Cassini mission in particular means that NASA only process a tiny percentage of all the data they amass. They simply do not have the resources or manpower to process everything, or even a sizeable percentage. Then, there is the immediacy of processing images taken only a few hours previously: this 'hot off the press' turnaround gives the public a real sense of what is happening out in space - not months or years ago. I particularly enjoy seeing the reactions of fellow image processors and lay people alike, as they digest the newest vistas, often of moons that have hitherto never been seen in such detail or close quarters. That, to me, is the thrill of space exploration in a nutshell!



Ken Sturgill; NASA/JPL-Caltech/Space Science Institute/SwRI/MSSS/Betsy Asher Hall/Gervasio Robles/Gerald Eichstädt/Alexis Tranchandon/Solaris/
Sean Doran/Kevin M. Gill, Stephane Calonnec, G. Ugarkovic, Emily Lakdawalla, Adam Hurcewicz, Earnest Hamby, Judy Schmidt, Bjorn Jonsson,

## SOPHIA NASR

**Sophia Nasr is studying for a PhD in Cosmology at the University of California, with a focus on dark matter. While academic research is mainly what she does, she also likes doing scientific outreach via her popular blog, Twitter, and other social media outlets. She only started processing planetary images a few months ago, and her favourite mission for this is Cassini.**

**Tell us how the Cassini mission inspired you to begin processing images...**

I began processing images when Cassini made its first of 22 Grand Finale dives between Saturn and its rings. It became more real to me that Cassini was ending, and I was emotionally moved to bring images to life during this period. So I found a blog post by Emily Lakdawalla that discussed how to process. And that was it! My first image was Saturn's polar vortex from Cassini's first dive, and it went pretty viral, showing up in just about every article that was posted on Cassini's first Grand Finale dive!

**Has the work of any other processors inspired you at all?**

My biggest inspiration was Jason Major – his images are so beautiful, and I wanted to give it a try! He has also given me tips to get better results.

**Your Cassini images have been shared many times on Twitter and appeared on many websites. Which is your favourite?**

I think my favourite is the one in which Cassini captured the opposition effect on Saturn's rings, taken on 12 June 2007. I was so excited about this one that I wrote a blog post on the phenomenon! The colour of Saturn and its rings is near perfect (in my view), and the alignment of the frames was done very well. This is definitely my favourite image.

**Do you use any specialised software in your processing work?**

I use Adobe Photoshop CS6 to process my images. I get frames in the red, green and blue filters from the raw Cassini images website, align them and then combine them for a colour composite. Then, I apply various tweaks to make the image look better. And voilà! I get a colour image out!

**What is it about processing images that you enjoy the most?**

I process images because it gives people a chance to see Saturn and its moons and rings in colour as soon as they're released. I enjoy it because it gives me the opportunity to be creative and take a break from academia. I also like explaining some of the cool physics that we see in some of the images on my blog, so by processing images, I get to participate in art and scientific outreach! I really enjoy it.

> "Most of the scientists involved in interplanetary missions now realise how important it is for the public to feel involved"

Although we'd never admit it, space enthusiasts are spoiled rotten these days. We take for granted that we live at a time when the Solar System is scattered with space probes exploring its incredible planets, moons and small bodies. Look up at a planet in the night sky and there's a good chance it's either being studied by a robot sent from Earth at that very moment, or was recently. We also take for granted the fact that these incredible machines – designed, built, launched and operated by equally incredible people back on Earth – take and beam back to Earth new stunning photographs of planets, moons, comets and asteroids almost every day. We can see these images on our computers at home, or on our phones or tablets sitting on the bus remarkably quickly.

The internet has changed everything, but before that, space enthusiasts had to be very, very patient. Just like today, we would spend years looking forward to a probe flying past a planet or comet, or landing on it, but after it had happened there was always a long and frustrating wait before we saw anything. There might be a photo or two on the TV news that night or in the newspapers the day after an encounter or landing – official images released to the media by NASA or ESA – but that would be it. There would then be a long wait before the media published photos.

Today we see images taken 'out there' after merely a very short delay. When the Juno probe flew over Jupiter's Great Red Spot in July 2017 the images were posted online by NASA just a couple of days later. For the past ten years the Cassini team has posted images of Saturn's clouds, rings and moons the day after they were taken, sometimes even sooner. Ever since the Mars Exploration Rover Opportunity landed on the Red Planet back in 2004, her team has posted her images of the Martian landscape often on the same day (or 'sol') they were taken, or sometimes within a few hours of being snapped.

So, compared to the days of Pioneer, Viking and Voyager we are living in a golden age of space exploration. Images of distant worlds are available for us to drool over on our pocket computers mere days, or even hours, after they were taken by our robotic deep space ambassadors. But, for some people, simply perusing images isn't enough.

Today there are many people who take the images released by NASA and ESA, and other space agencies, and use them to create new shots. This simply wasn't possible before the space agencies began releasing their images freely on websites, quickly, and in large numbers, instead of just a handful at a time. In fact, the key to these image processors' success is the enthusiasm of the space agencies for their efforts, and their willingness, to release their images so quickly and freely. Most – though not all, it has to be said – of the scientists involved in interplanetary missions now realise how important it is for the public to feel involved in their missions, and encourage people to take their images and have fun with them – which many think is only right. After all, modern space missions are hugely expensive and funded by the public through taxes, so it is only fair that the people who pay for the missions should get to see the photos taken by them, right?

Well, within reason. Planetary scientists dedicate years – sometimes decades – of their lives to the space missions they work on, so it's unfair and selfish to expect them to release every image their missions take as soon as they are taken. They need to have time to use those images in their research, and to make the discoveries they were hoping to make. Imagine if you'd put ten years of your life into a space mission, sweated over it for the whole of your professional life, only to have your moment of triumph, your great discovery, stolen from you by someone sat at home in their pyjamas... Someone messing about with your images on their tablet who

spots something new or unusual whilst wolfing down a takeaway with the TV blaring...

This is why NASA and ESA release so-called 'raw' images, which means they are uncalibrated, compressed JPEGs, not images taken in the RAW format DSLR cameras take. These are good enough for people to look at and work with, but not of a high enough quality to use for serious research and data analysis.

So what do these image-processing enthusiasts do? And why do they do it?

While it's true that the most prolific image processors use high-spec machines, specialised software (some of it written by themselves) and very complicated processing techniques, others simply use popular everyday photo-processing software like Photoshop or GIMP. These can enhance the raw images released onto the internet in ways that bring out the subtle details and features not visible on the originals. For example, the images of Saturn's clouds released by the Cassini mission can look quite bland and featureless at first glance, just as they would to the naked eye if you were gazing down on them from a spacecraft. However, with a little sharpening and tweaking of brightness and contrast, it is possible to bring out subtle details – whirls and twirls of cream-in-coffee cloud – in Saturn's atmosphere, not immediately apparent on the originals.

Others download series of images and combine them in different software packages to create long, panoramic views. Images taken by landers or rovers on the surface of Mars are very popular for this. By stitching together half a dozen separate images taken in a sweeping, panning movement by their cameras, it is possible to create beautiful and lifelike portraits of the Martian landscape. Panoramas showing its distant, rolling hills, rock-strewn plains and butterscotch-coloured sky, all give an idea what it would be like to stand on Mars for real. Some processors then go even further and digitally drop an image of the rover, or even an astronaut, into the image to show the true scale of the landscape.

Other image processors combine images to make animations or short films, or 3D anaglyph images, which can be viewed with red and blue glasses. These really bring the Martian landscape to life, and make you feel like you could reach out and touch the planet's rugged rocks, or trudge up its dust-covered slopes. With an eye on the next generation of armchair exploration, some processors are now even creating 3D landscapes to be explored in VR.

While many image processors are happy just to create images for use on their own websites or blogs, others create images specifically for serious public outreach, to support and promote the missions. They create incredibly detailed and accurate images, which are so beautiful and so impressive, the space agencies happily feature them on their websites and use them as promotional material.

As Dr Mark McCaughrean, the senior advisor for Science & Exploration at the European Space Agency, says: "The image processor crowd do a good job, and many are very talented, bringing skills in from other fields (such as VFX, 3D modelling). They can do more as a crowd than we can often, and that's very positive. “

Different processors have different approaches. Some process images very subtly and carefully, taking great pains to make them look as realistic and natural as possible. They recreate the view – as best they can – that you would see with your own eyes if you were flying around Jupiter or Saturn or standing on Mars. Others process images much more aggressively, dragging as much detail out of them as possible. This often results in 'false colour' images with quite bold or even garish colour schemes, which their creators acknowledge bear no resemblance to reality whatsoever. Some people condemn them as being over-the-top or 'overcooked', but that's missing the point: they are not claimed to be realistic, but are deliberately over-processed to show features and structures not visible otherwise – something NASA and ESA do with their own images all the time.

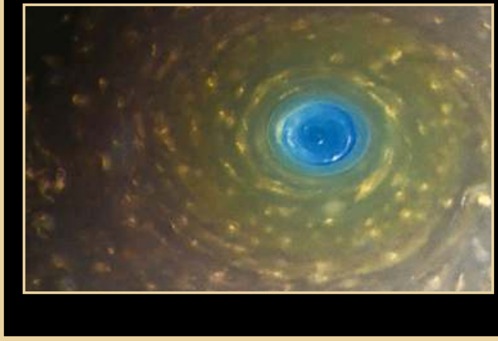
Manipulating and processing space-related images isn't new. For decades, even before the invention of digital SLR cameras, astrophotographers have been taking multiple images of celestial objects and stitching them together to make large, single

## JASON MAJOR

**Jason Major is a freelance graphic designer living in Warwick, Rhode Island, USA. He enjoys following the latest space news stories, and likes to process images quickly when they are released from missions like Cassini and Juno. Jason is very active on Twitter, where he enjoys sharing images from past missions, both robotic and human.**

**How did you get started in processing images?**

I started a little after I began my space-themed blog, **LightsInTheDark.com** in February 2009. I was sharing images from Cassini and the Mars Exploration Rovers a lot, and I was learning about image processing on sites like **unmannedspaceflight.com** and The Planetary Society's blog by Emily Lakdawalla. There I saw how to use Photoshop to combine raw spectral image data to make full-colour versions. Being able to turn monochrome images into colour versions that approximated what our eyes would see is a real treat… it's a technique that's simple to learn but hard to master – I'm still learning new ways to do it better.



**Which mission has inspired you the most?**

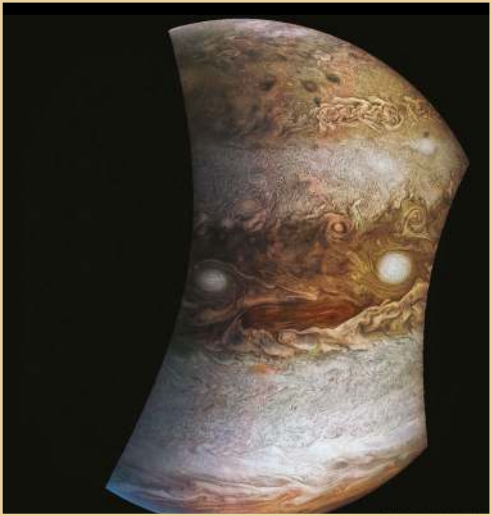
For the majority of my time processing images I have been most inspired by Cassini. Saturn is such a glorious world, and there's no shortage of beautiful vistas from the giant ringed planet and its family of moons.

**Out of all the images you've processed, which is your favourite – and why?**

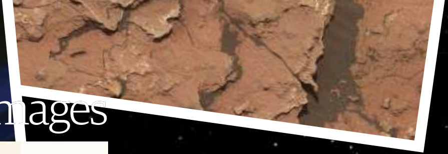
This is a tough choice since I've done so many images over the years, but one of my all-time (and also recent) favourites is a view of Saturn's north polar vortex. It's made from raw JPEGs from Cassini captured on 29 March 2017, and I love how perfectly circular and calm the eye of Saturn's vortex looks. When you realise you're looking down into a 'pool' of clear air that would stretch a third of the way across the U.S., it's really incredible.

**Tell us a little about the hardware/software you use in your work...**

I use Photoshop primarily, with some additional filtering using Nik software – that is if I'm feeling particularly creative. I work on a MacBook Pro, both for business and pleasure. I've been a faithful Mac user since the mid 1990s, and I'll stay that way for the rest of my days.



Sometimes, when I'm processing some of the raw data from Juno, I'll run it through Lightroom first. I do have some processing scripts set up there to help me quickly edit the Juno RGBs when they arrive on Earth. This workflow has helped me get some of the first processed images online from its perijove passes, which worked out in my favour when NASA used one in their July press release!



images. Unless you have a very wide-angle or fisheye lens, this is actually the only way to take a good panoramic image of the Milky Way. If a really big display of the northern lights or noctilucent clouds kicks off, taking multiple shots and stitching them together to make a single, sweeping panoramic view is the only way to do it justice. Astro-imagers who attach cameras to their telescopes to take close-up photographs of deep sky objects such as galaxies, star clusters and nebulae, take dozens or sometimes hundreds of photos of the same object then combine them in a process called 'stacking', which reduces background noise and brings out subtle details and features not visible on a single image.

Long before Juno stared down into the cinnamon-hued heart of Jupiter's Great Red Spot, and decades before Cassini sent back its first breathtaking images of geysers erupting in plumes of glittering mist from the south pole of Saturn's icy moon Enceladus, images taken by space missions were being manipulated and processed. When Mariner 4 flew past Mars in 1965 it sent back the historic first images ever taken of another world by a space probe. As is the case today, the data returned by the probe needed processing before it could be turned into images that could be viewed. But, so impatient to see the surface of Mars were the team behind the mission that they took the strips of numbers returned by Mariner, pasted them onto a huge board and coloured them in by hand. The result - a very vague, low-resolution 'image' of the curved limb of Mars, the first time it had ever been seen.

Seven years later, Mariner 9 went into orbit around Mars, taking hundreds of detailed images showing the planet's volcanoes, craters and canyons. Today's planetary scientists use sophisticated photo-stitching software to quickly combine such photographs into single images, but in 1972, such computer sorcery was still a generation away. The only way to turn these individual images into a large-scale single image was to print them out, trim them with a knife and tape them together by hand, like the pieces of a jigsaw puzzle - and that's exactly what NASA scientists like Patricia 'Patsy' Conklin did to create not only large collages, but detailed globes, too.

But the public didn't get a proper chance to manipulate and process images taken by space probes until 4 July 1997, when NASA's Pathfinder mission successfully reached Mars. The lander carried a small, microwave oven-sized rover, Sojourner - recently seen in the film *The Martian*, following stranded astronaut Mark Watney around like a puppy - which rolled off the lander, trundled down a ramp and then set about exploring its landing site. It was hoped that Sojourner would last a week on the Red Planet before it succumbed to the harsh Martian environment, but it heroically spent the next 85 days driving inquisitively around Ares Vallis, going from rock to rock, taking measurements and photos.

The Pathfinder mission to Mars revolutionised public access to, and demand for, space exploration images. Not because of the sheer number of images taken on the surface of Mars, but because NASA took the decision to post images taken by the mission on the internet, soon after they were taken, for anyone and everyone to see. Not all the images were put online of course - the lander took more than 16,000 images and the Sojourner rover a further 550 - but enough were put online to trigger a digital feeding frenzy amongst space exploration enthusiasts, the media and the general public.

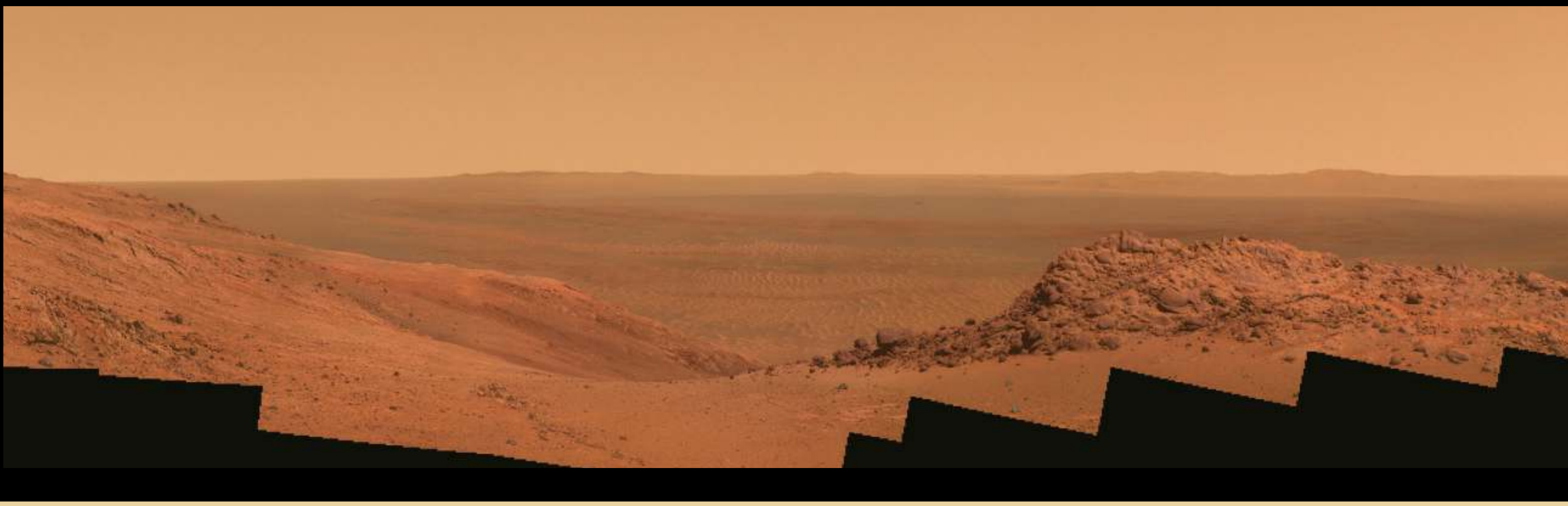
Today the entertainment media like to say how a celebrity selfie taken at an awards ceremony or a photo of a celebrity TV star's new baby or surgically enhanced bottom 'broke the internet' but the Pathfinder mission almost did it for real. Between Pathfinder's historic landing day on 4 July and 8 July, the mission's website received a staggering 200 million hits, a traffic record at the time. A month later, that number had increased to 566 million.

## JAMES SORENSON

**A veteran image processor, James has lived in a small town in Oregon, called Clatskanie, since around 1997, and his image processing work is very popular and highly respected in the image processing community. His favourite mission to process images from is the Mars Exploration Rovers (MER) mission, of which he says: "Curiosity is great and all, but I particularly get bored with how easy it is to process the images. I like the challenge, and MER imagery is every bit as such. I'm familiar with it."**

**How did you get started in processing images?**
I got interested in space at a very early age. In the mid 1990s I recall getting excited about NASA and the space program by watching space shuttle launches. Every launch fascinated me more and more, I'd record each launch then play them back to show family and friends over and over until the VCR started eating them. One NASA rocket launch in particular peaked my interest about Mars when I watched it live, and that was Mars Pathfinder and Sojourner. I thought it was the neatest thing that we could actually send something to Mars and drive something around on another world. At that age, I knew absolutely nothing about previous missions that we had sent there, or anything about Mars in general. I started researching the subject and learning more and more about the planets and missions not only to Mars, but to other places in our Solar System. When Spirit and Opportunity were being built, I'd check the NASA/JPL and Athena Cornell websites every day for updates on their progress, and right after they landed, that's when I started learning about image processing and how to work on them.

**Out of all the images you've processed, do you have one that you're particularly proud of?**
This is a tough one. I actually really don't have a particular favourite image that I've produced. Every one that I do, I feel I improved more and more every time as time goes on. I especially love seeing and doing images with rover tracks and hardware in the same picture of the Martian landscape. They give



It's hard to understate how huge a paradigm shift this was. Space enthusiasts desperate to see the images taken by the lander and its rover of the surface of Mars could see them, almost straight away, for free, on their computer screens at home, or in the local library or at school. The media could see the images too, and use them to write or film stories about the mission.

This is when image processing enthusiasts began to use space mission photographs to create new and exciting images. After saving Pathfinder and Sojourner images to their hard drives with a deft right click, they stitched them together to make panoramas of the landing site and its countless rocks and boulders. Because of the limitations of the software available in those days, these early products were quite crude, often poorly aligned and distorted, but that didn't matter. The genie was out of the bottle. No longer were images taken by a space mission reserved for the men and women working on it; anyone with internet access could grab them and have fun with them. It was the beginning of a revolution in space imaging.

Then came the Mars Exploration Rovers. The MER mission stepped image release up a gear by posting every image taken by its twin rovers, Spirit and Opportunity, to online galleries, sometimes after just a few hours. This was a conscious decision made by the mission team. They said from the start that they wanted the MER mission to excite and inspire as many people as possible, and the obvious way to do this was by showing those people what the rovers themselves were seeing.

Having enjoyed a trickle of images from the Pathfinder mission, the image processing enthusiasts cheered and clapped as the MER floodgates opened, giving them access to dozens, sometimes hundreds, of new images every day. Suddenly websites, blogs and forums such as **unmannedspaceflight.com** were full of amazing panoramas, colourisations and 3D anaglyphs, produced by what are now known as 'citizen scientists' on their own computers at home, before or after a hard day at work.

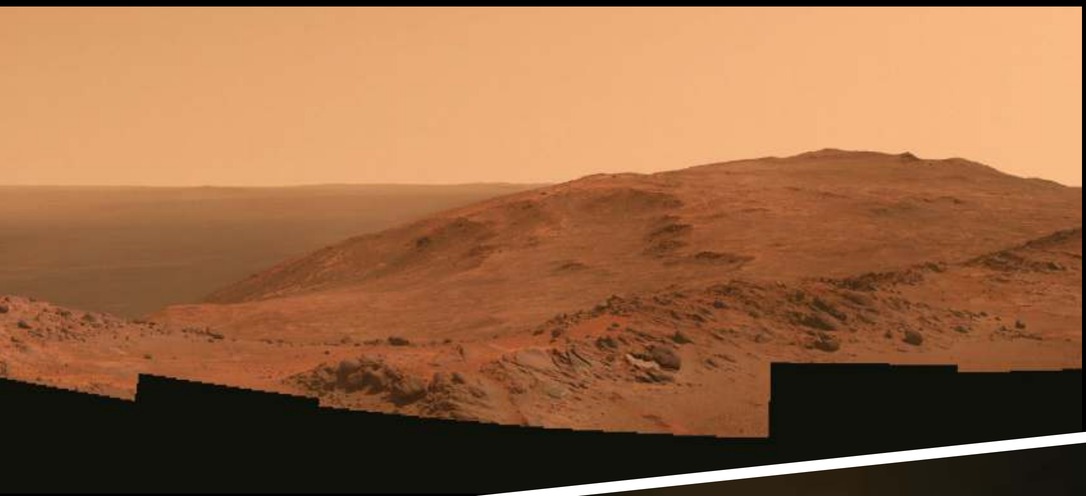
Today the value of releasing images to the media and the public quickly and freely is recognised by most space missions. Most teams post at least some of their 'raw' images online soon after they are taken, which allows the public to see them, the media to share them and image processing enthusiasts to use them to create new images. Stunning panoramas and mosaics were produced by enthusiasts literally within minutes of raw images taken by the Curiosity, Rosetta and New Horizons missions appearing on the NASA and ESA websites.

a sense of being there more. It provides a sense of scale, and makes you realise what people can accomplish when they come together and do something great.

**What do you get out of image processing?**

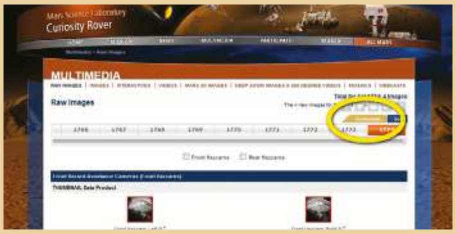
This might be an obvious and very simple worded answer... It's fun! Sure, it's great to see NASA image releases, but working on them yourself and learning techniques to work on the images to produce a pleasing result, and then say to myself "Hey, I took those three horrendously noisy images and cleaned them up to combine into one colour picture of Mars. This was taken, in many circumstances, just a couple of hours ago from another world I can now see with my own eyes. I thank the mission teams of not only Spirit and Opportunity, but every NASA project that releases the raw images to the public.

> "This was taken just a couple of hours ago from another world I can now see with my own eyes" **James Sorenson**

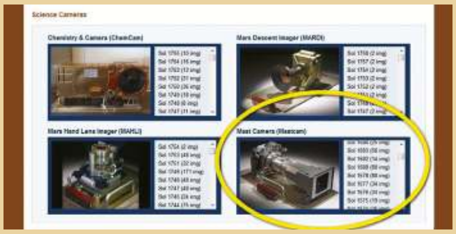


QUICK TUTORIAL

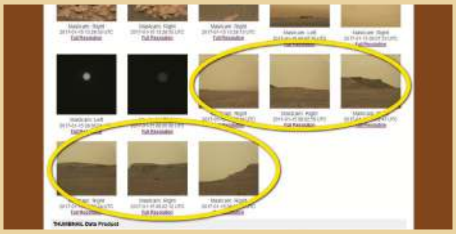
## Create a panoramic Martian landscape from Curiosity data



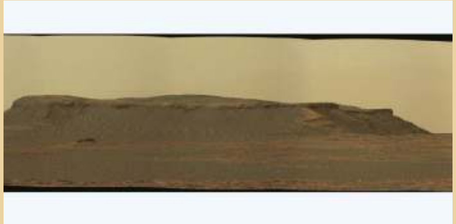
1 Go to NASA's Mars Curiosity images page and click on the 'Instrument' tab.



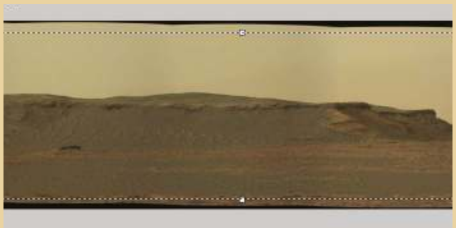
2 Select Mastcam, scroll through entries looking for a 'sol' on which a series of images was taken suitable for stitching into a single image.



3 Save these images to your computer. Load these images into an image-stitching program.



4 The program will generate a panoramic image from the individual images.



5 Crop the image to remove the uneven borders until you have something that looks like an eight.

# STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

# What's in the sky?

## 15 SEP

Conjunction between the Moon and dwarf planet Ceres in Cancer and Gemini

©Mike Lewinskiv

## 16 SEP

Conjunction between Mercury and Mars in the dawn sky in Leo

## 21 SEP

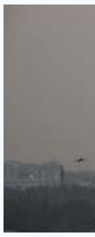
The Piscids reach their peak of around five meteors per hour

## 21 SEP

Conjunction between the Moon and dwarf planet Makemake in Virgo

## 22 SEP

September equinox



## 27 SEP

The Moon and Saturn make a close approach of 3°27' in Ophiuchus

©Thomas Bresson

## 29 SEP

Conjunction between the Moon and dwarf planet Pluto in Sagittarius

## 1 OCT

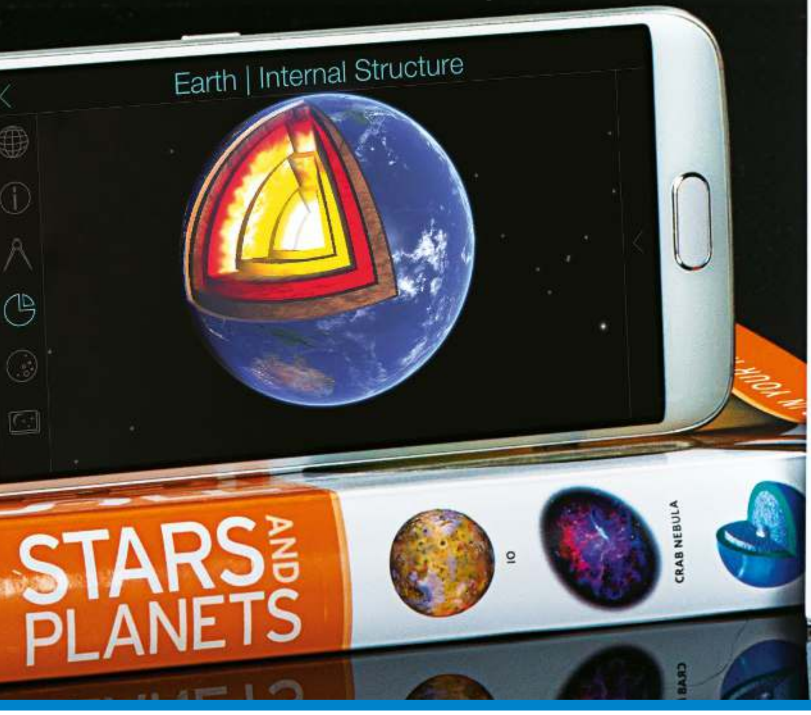
The Andromeda Galaxy's satellite galaxy M32 can be observed in Andromeda

## 3 OCT

The Moon and Neptune make a close approach of 0°42' in Aquarius

## 6 OCT

Conjunction between the Moon and dwarf planet Eris in Cetus



## Jargon buster

### Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

### Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

### Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

### Magnitude

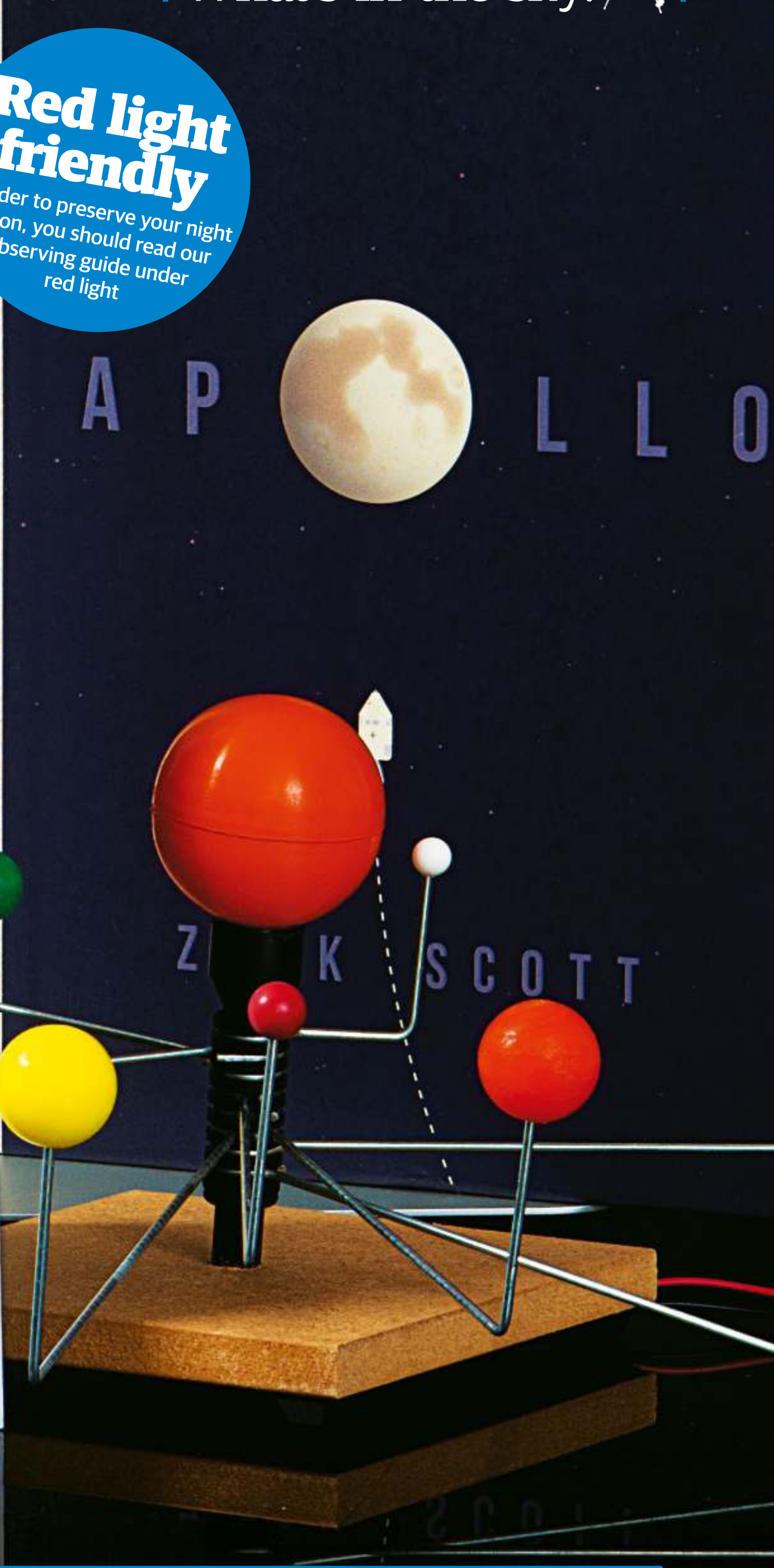
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

### Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

### Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.



## Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

**18 SEP**
Conjunction between the Moon and Venus in the dawn sky in Leo

**19 SEP**
Conjunction between the Moon and Mercury in the dawn sky in Leo

©Adam Evans

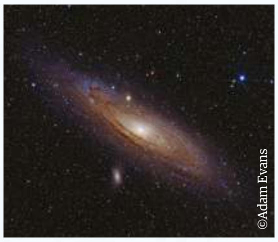
©Biswarup Ganguly

**22 SEP**
Conjunction of the Moon and dwarf planet Haumea in Virgo and Boötes

**24 SEP**
Barred spiral galaxy NGC 55 is well placed for observation in Sculptor

**1 OCT**
The Andromeda Galaxy's satellite galaxy M110 is well placed in Andromeda

**1 OCT**
The Andromeda Galaxy (M31) is well placed for observation in Andromeda


©Adam Evans

**8 OCT**
Mercury reaches its greatest brightness of -1.7 in the evening sky in Virgo

**8 OCT**
Conjunction between Mercury and Makemake in Virgo and Coma Berenices

Naked eye
Binoculars
Small telescope
Medium telescope
Large telescope

## In this issue...

**74 What's in the sky?**
With summer's end comes darker skies to bring those fainter objects into view

**78 Month's planets**
Behold the bright beauty of Venus, while Mercury and Mars make a close pass

**80 Moon tour**
The time is now to find one of the most famous craters to grace the silver screen

**81 This month's naked eye targets**
Find the Demon Star and look into the eye of a Gorgon

**82 How to... work out stellar magnitudes**
Determining the estimated brightness of celestial bodies

**84 Deep sky challenge**
Turn your telescope to some tricky deep-sky targets visible this autumn

**86 How to... snap the planets**
Use a smartphone to image the planets easily and clearly

**88 The Northern Hemisphere**
The Swan and the Sea Goat offer stunning celestial sights

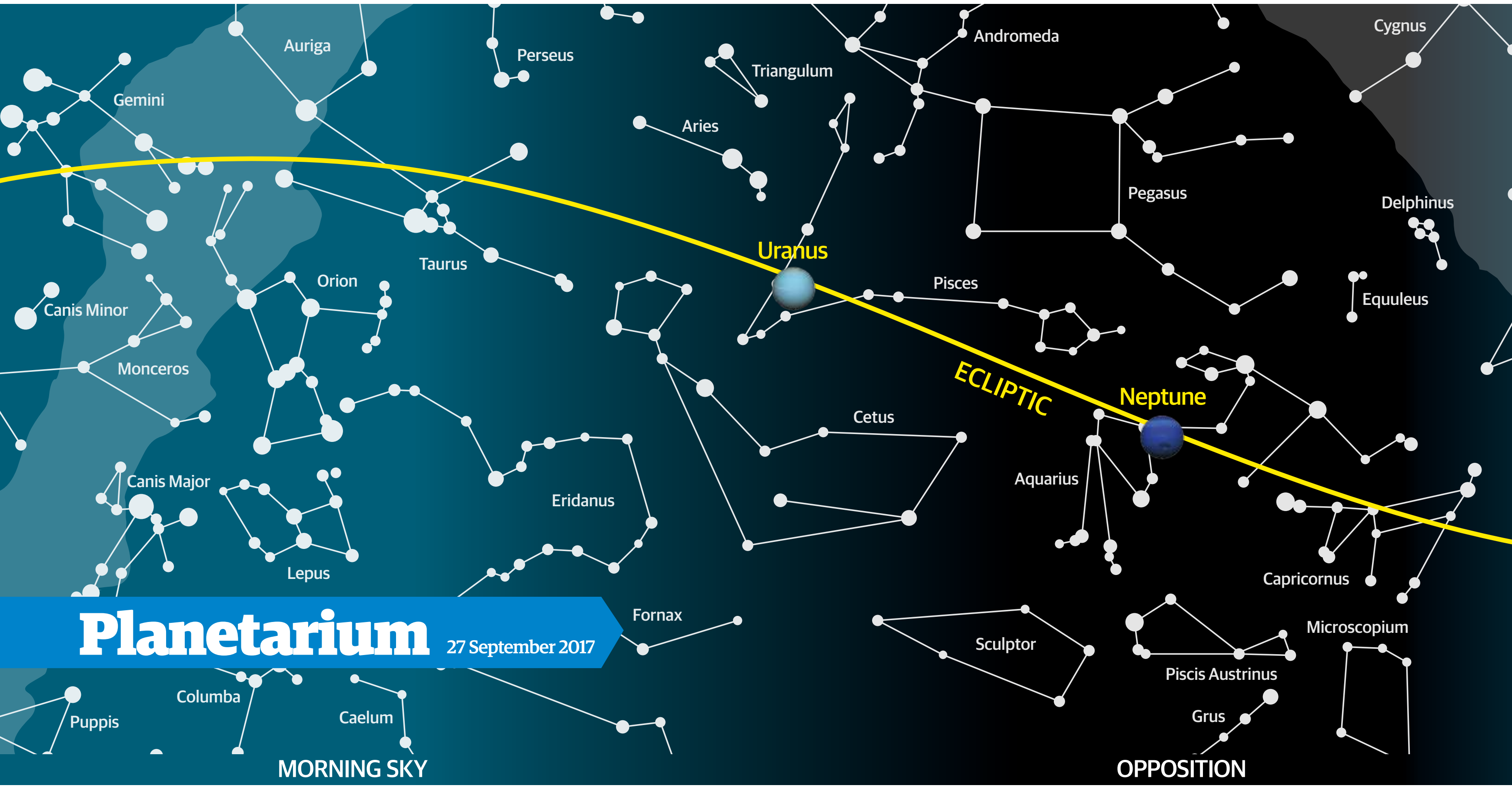
**90 Astroshots of the month**
Your favourite astroimages showcased this issue

**96 In the Shops**
Our monthly pick of some of the best telescopes, accessories and software

# STARGAZER

## Planetarium

27 September 2017



## Moon phases

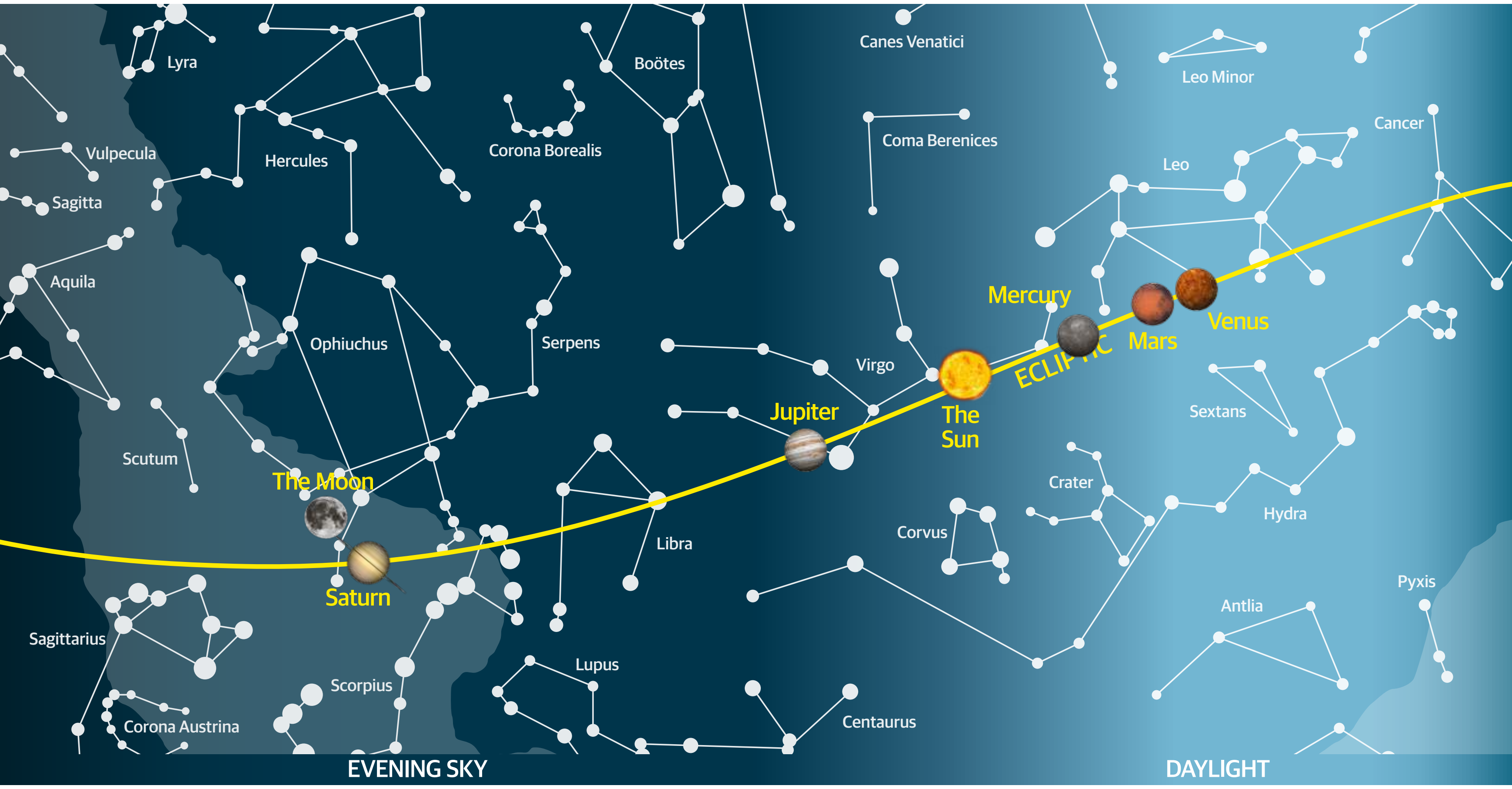
* The Moon does not pass meridian on 4 October

| Date | Phase | Illumination | Times |
|---|---|---|---|
| 14 SEP | | 38.5% | ▲--:-- ▼15:51 |
| 15 SEP | | 27.3% | ▲00:44 ▼16:44 |
| 16 SEP | | 17.4% | ▲01:50 ▼17:28 |
| 17 SEP | | 9.5% | ▲03:01 ▼18:05 |
| 18 SEP | | 3.8% | ▲04:14 ▼18:37 |
| 19 SEP | | 0.7% | ▲05:28 ▼05:28 |
| 20 SEP | NM | 0.2% | ▲06:41 ▼19:29 |
| 21 SEP | | 2.1% | ▲07:52 ▼19:53 |
| 22 SEP | | 6.1% | ▲09:02 ▼20:17 |
| 23 SEP | | 12.0% | ▲10:09 ▼20:42 |
| 24 SEP | | 19.3% | ▲11:14 ▼11:14 |
| 25 SEP | | 27.7% | ▲12:17 ▼21:41 |
| 26 SEP | | 36.9% | ▲13:17 ▼22:17 |
| 27 SEP | | 46.5% | ▲14:12 ▼22:58 |
| 28 SEP | FQ | 56.3% | ▲15:02 ▼23:46 |
| 29 SEP | | 65.9% | ▲15:46 ▼--:-- |
| 30 SEP | | 75.1% | ▼00:41 ▲16:25 |
| 1 OCT | | 83.4% | ▼01:41 ▲16:59 |
| 2 OCT | | 90.5% | ▼02:46 ▲17:29 |
| 3 OCT | | 95.9% | ▼03:55 ▲17:56 |
| 4 OCT | | N/A* | ▼05:07 ▲18:22 |
| 5 OCT | FM | 99.1% | ▼06:21 ▲18:47 |
| 6 OCT | | 99.8% | ▼07:37 ▲19:14 |
| 7 OCT | | 97.7% | ▼08:54 ▲19:43 |
| 8 OCT | | 92.9% | ▼10:13 ▲20:16 |
| 9 OCT | | 85.5% | ▼11:29 ▲20:55 |
| 10 OCT | | 76.0% | ▼12:42 ▲21:42 |
| 11 OCT | | 76.0% | ▼13:47 ▲22:37 |
| 12 OCT | LQ | 65.0% | ▲14:43 ▼23:41 |

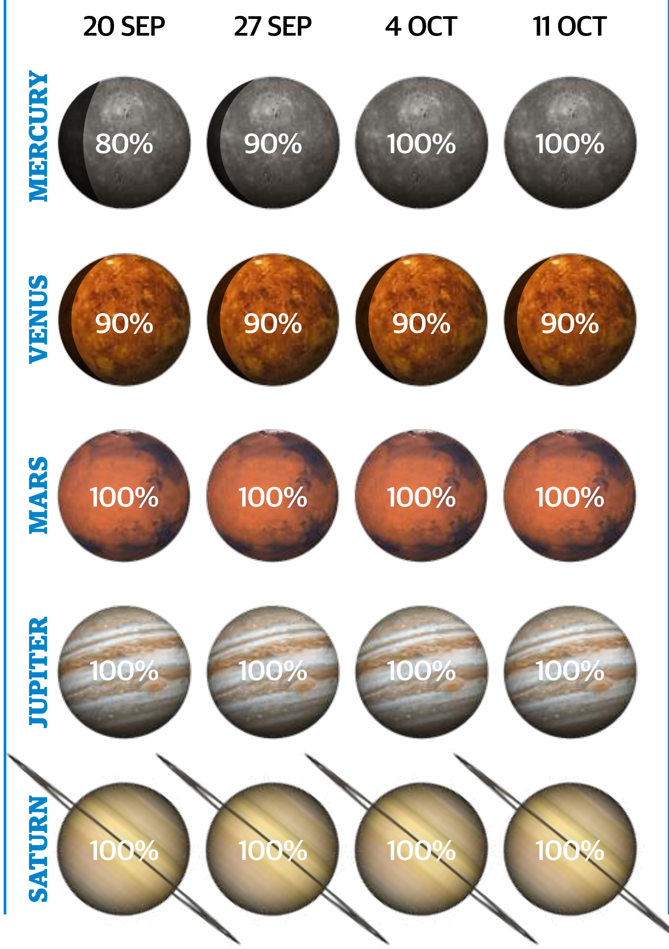
% Illumination
▲ Moonrise time
▼ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



## Illumination percentage



| | 20 SEP | 27 SEP | 4 OCT | 11 OCT |
|---|---|---|---|---|
| **MERCURY** | 80% | 90% | 100% | 100% |
| **VENUS** | 90% | 90% | 90% | 90% |
| **MARS** | 100% | 100% | 100% | 100% |
| **JUPITER** | 100% | 100% | 100% | 100% |
| **SATURN** | 100% | 100% | 100% | 100% |

## Planet positions

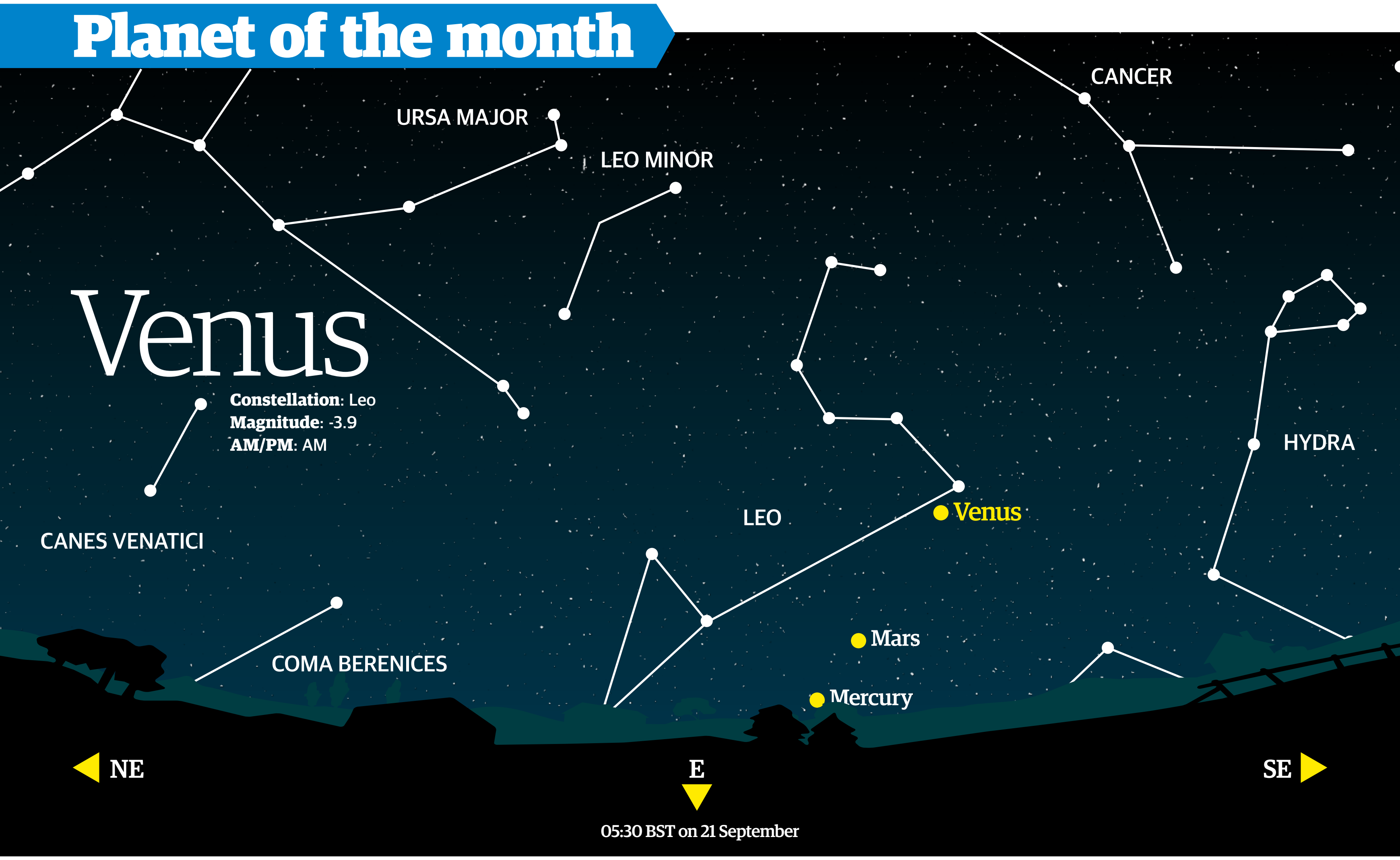
All rise and set times are given in BST

| | Date | RA | Dec | Constellation | Mag | Rise | Set |
|---|---|---|---|---|---|---|---|
| **MERCURY** | 14 Sep | 10h 22m 13s | +10° 57' 30" | Leo | -0.6 | 04:48 | 18:48 |
| | 20 Sep | 10h 55m 53s | +08° 34' 20" | Leo | -1.0 | 05:10 | 18:45 |
| | 27 Sep | 11h 41m 49s | +03° 59' 13" | Virgo | -1.2 | 05:52 | 18:40 |
| | 04 Oct | 12h 27m 54s | -01° 21' 14" | Virgo | -1.5 | 06:38 | 18:31 |
| | 11 Oct | 13h 12m 12s | -06° 41' 09" | Virgo | -1.5 | 07:21 | 18:21 |
| **VENUS** | 14 Sep | 09h 39m 56s | +14° 41' 53" | Leo | -3.9 | 03:45 | 18:27 |
| | 20 Sep | 10h 08m 32s | +12° 26' 38" | Leo | -3.9 | 04:02 | 18:19 |
| | 27 Sep | 10h 41m 24s | +09° 32' 43" | Leo | -3.9 | 04:23 | 18:08 |
| | 04 Oct | 11h 13m 47s | +06° 25' 01" | Leo | -3.9 | 04:44 | 17:57 |
| | 11 Oct | 11h 45m 52s | +03° 07' 28" | Virgo | -3.9 | 05:06 | 17:44 |
| **MARS** | 14 Sep | 10h 29m 56s | +10° 41' 08" | Leo | 1.8 | 04:57 | 18:54 |
| | 20 Sep | 10h 44m 17s | +09° 16' 17" | Leo | 1.8 | 04:55 | 18:37 |
| | 27 Sep | 11h 00m 52s | +07° 34' 59" | Leo | 1.8 | 04:53 | 18:18 |
| | 04 Oct | 11h 17m 18s | +05° 51' 44" | Leo | 1.8 | 04:51 | 17:57 |
| | 11 Oct | 11h 33m 38s | +04° 07' 01" | Leo | 1.8 | 04:51 | 17:57 |
| **JUPITER** | 14 Sep | 13h 31m 23s | -08° 24' 26" | Virgo | -1.7 | 09:36 | 20:17 |
| | 20 Sep | 13h 35m 54s | -08° 51' 24" | Virgo | -1.7 | 09:19 | 19:56 |
| | 27 Sep | 13h 41m 20s | -09° 23' 16" | Virgo | -1.7 | 08:59 | 19:31 |
| | 04 Oct | 13h 46m 53s | -09° 55' 23" | Virgo | -1.7 | 08:40 | 19:06 |
| | 11 Oct | 13h 52m 34s | -10° 27' 31" | Virgo | -1.7 | 08:21 | 18:42 |
| **SATURN** | 14 Sep | 17h 22m 12s | -22° 01' 57" | Ophiuchus | 0.5 | 14:44 | 22:49 |
| | 20 Sep | 17h 22m 12s | -22° 03' 52" | Ophiuchus | 0.5 | 14:22 | 22:26 |
| | 27 Sep | 17h 24m 31s | -22° 06' 18" | Ophiuchus | 0.5 | 14:22 | 22:26 |
| | 04 Oct | 17h 26m 12s | -22° 08' 53" | Ophiuchus | 0.5 | 13:31 | 21:33 |
| | 11 Oct | 17h 28m 10s | -22° 11' 34" | Ophiuchus | 0.5 | 13:05 | 21:08 |

# This month's planets

Venus dazzles in the dawn sky alongside Mars and Mercury, while Saturn and Uranus take the night watch

## Planet of the month



### Venus

**Constellation**: Leo
**Magnitude**: -3.9
**AM/PM**: AM

05:30 BST on 21 September

The second planet from the Sun, and Earth's closest planetary neighbour, Venus is probably the planet most people – astronomers and non-astronomers alike – have seen in the sky. At its best it is a truly spectacular sight, outshining every other planet and every single star bar our own Sun.

As it whips around the Sun once every 224.7 days, Venus alternates between being visible before sunrise and after sunset, when it is known as either the 'Morning Star' or 'Evening Star', respectively. Most people see it when it is dominating the evening sky, when it becomes visible right after sunset as a silvery spark high in the south west, becoming brighter and more beautiful as the sky darkens. This month Venus will be in its 'Morning Star' role and will be a dazzling sight in the east before dawn, rising a good few hours before the Sun's light reaches us.

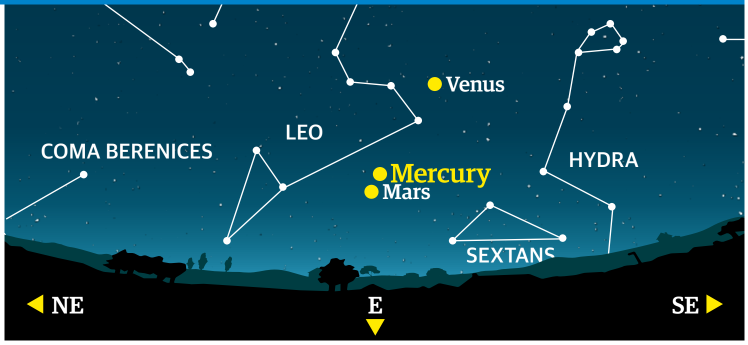
But why does Venus shine so brightly? Why is it often referred to as being lantern-bright?

It's because the planet is covered with a very dense atmosphere of choking carbon dioxide gas. Space probes that have flown past or orbited Venus saw only a blank, creamy, yellow-white disc. Its atmosphere is so thick there are never any gaps to allow its secret surface to be glimpsed. That dense cloudy shield acts like a huge mirror, reflecting the Sun's fierce light back out into space, and making Venus such a beautiful sight in our sky. It's no surprise that the planet was named after the Goddess of Love.

Ironically, the surface of the planet itself is the opposite of lovely. Sulphuric acid rain falls from the sky, but never reaches the rocky surface. Its air is poisonous carbon dioxide. The thick atmosphere traps the Sun's heat like the glass of a greenhouse, resulting in a surface temperature of more than 460 degrees Celsius (860 degrees Fahrenheit) – hot enough to melt lead. The atmosphere is also so thick and dense it creates extremely high pressure at the surface – 90-times higher than here on Earth. It might be beautiful to behold, but it is a very hostile place.

As our observing period begins, Venus will be blazing in the eastern sky before dawn, to the right of that well-known asterism the 'Sickle' of Leo, close to Leo's brightest star Regulus. As the days pass the 'Morning Star' will gradually slide to its lower left, passing Regulus between 19 and 21 September. They'll be closest on 20 September, less than half a degree apart in the sky, but more than 80 light years apart in reality. As October begins Venus will drift towards Mars, but will be less impressive as it falls towards the bright dawn sky.

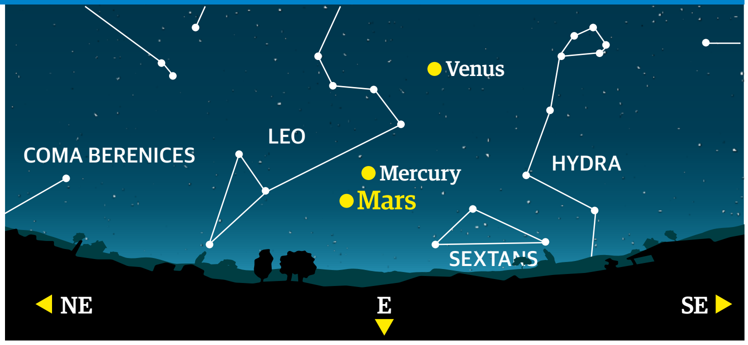
## Mercury 06:30 BST on 16 September



**Constellation**: Leo (then into Virgo)
**Magnitude**: -0.5
**AM/PM**: AM

At the start of our observing period Mercury will be shining at magnitude -0.5. It will look like an obvious star low in the east before dawn. On 14 September, Mercury will lie to the upper right of Mars, but the Red Planet will be much fainter. As the mornings pass, the two worlds will appear to close in on each other, until they have passed and swapped places by the morning of 20 September.

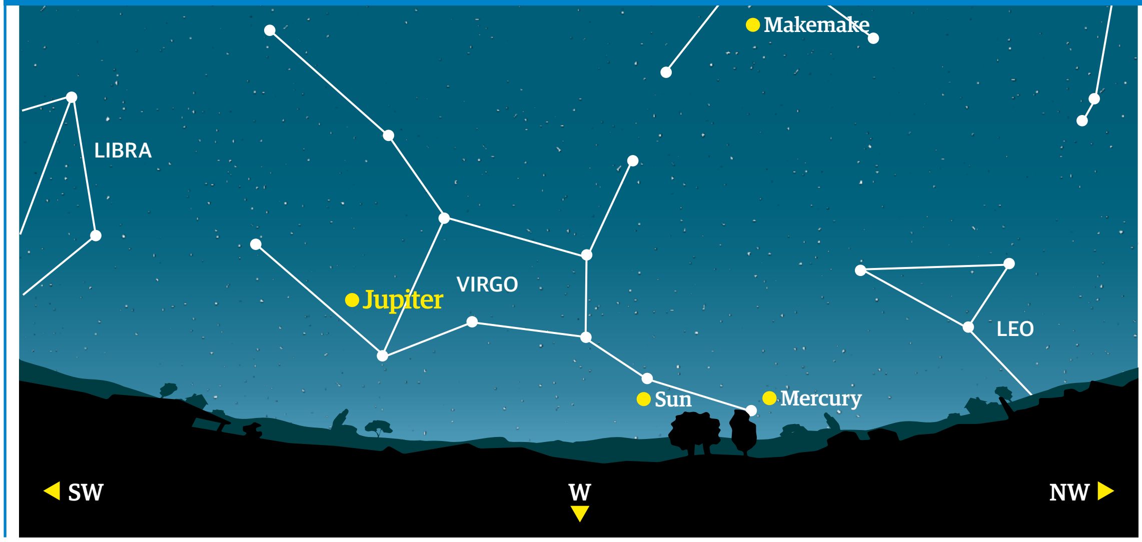
## Mars 06:30 BST on 15 September



**Constellation**: Leo
**Magnitude**: 1.8
**AM/PM**: AM

At a magnitude of 1.8 it is only slightly fainter than the Pole Star, Polaris, which will make it hard to see in the pre-dawn eastern sky. At the start of this period it will be found to the lower left of much brighter Mercury. After passing it on 20 September it will then be targeted by Venus for a planetary close-encounter. Through a telescope you might glimpse hints of dark features on its dusky surface.

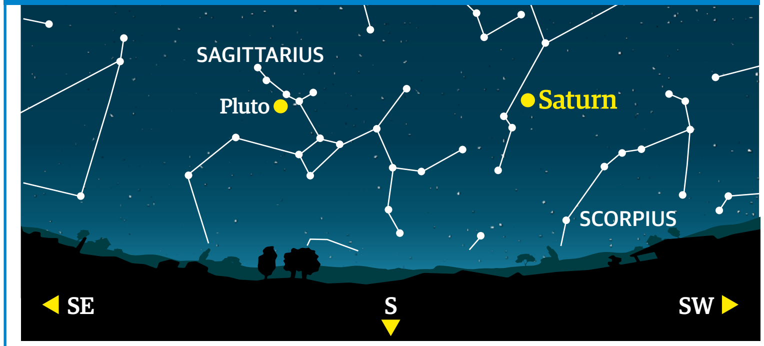
## Jupiter 18:30 BST on 27 September



**Constellation**: Virgo
**Magnitude**: -1.7
**AM/PM**: PM

This isn't a good time for sky-watchers who enjoy the gas giant. Jupiter is now so close to the Sun in the sky it sets at around the same time as our nearest and most important star. Its magnitude of -1.7 sounds respectable, and in a dark sky it would be a very bright object easily visible to the naked eye, but embedded so deeply in the evening sunset glow it won't be visible. Better to look at it through the eyes of NASA's hugely successful Juno probe, which is orbiting the planet and taking incredible photographs of its swirling storms and turbulent atmosphere. You can find the latest beautiful images taken by the space probe on its own dedicated website.

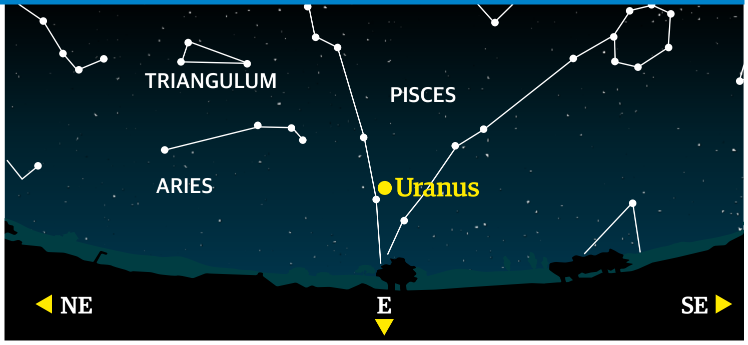
## Saturn 19:30 BST on 15 September



**Constellation**: Ophiuchus
**Magnitude**: 0.5
**AM/PM**: PM

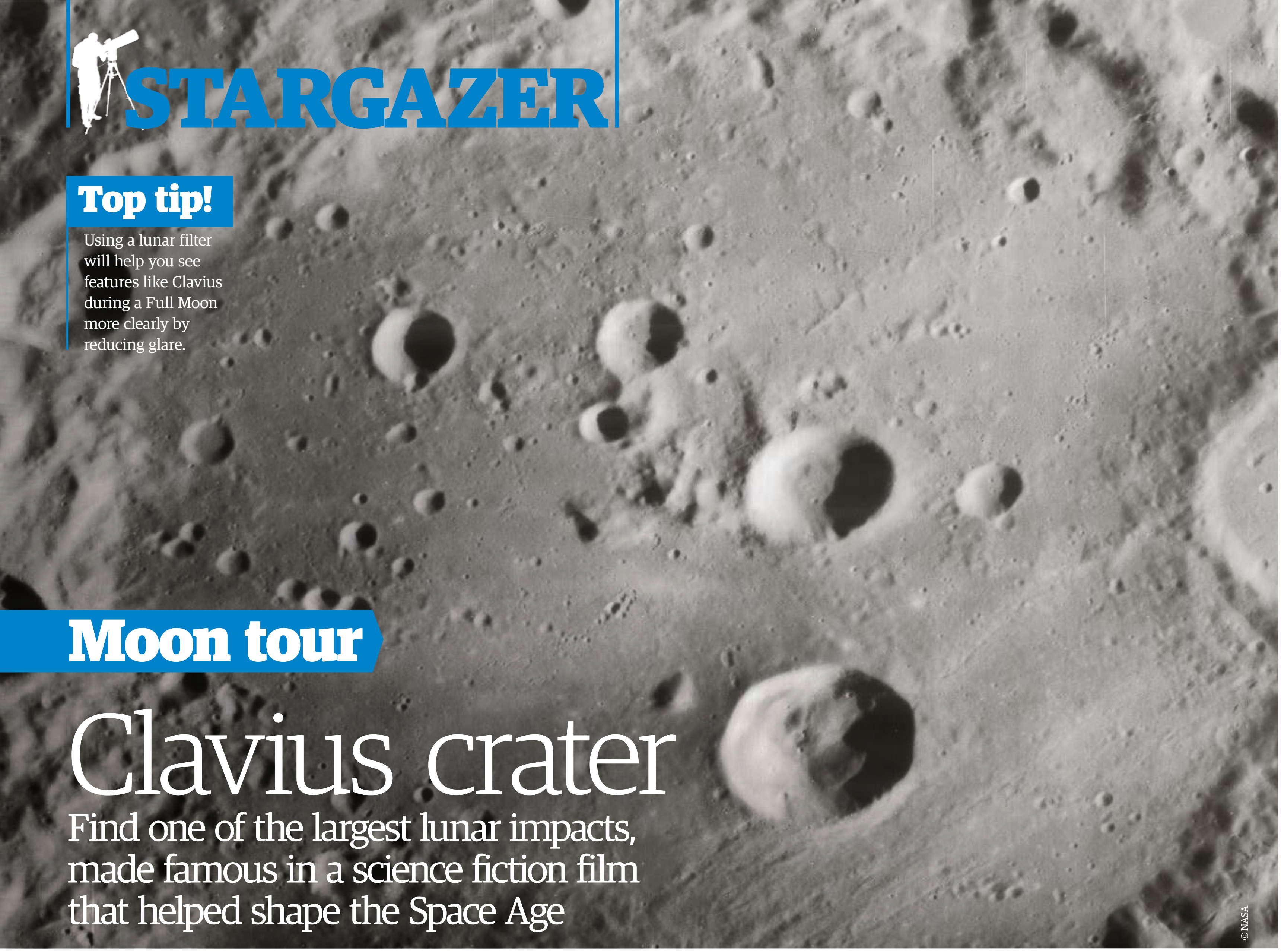
Saturn will be low in the south west after sunset, you'll find it shining to the upper left of bright-red star Antares. Between 25 and 27 September, the waxing Moon will approach, hang above and then pass Saturn. Binoculars won't show its rings, but will help you see Titan, its largest moon, looking like a 'star' close to the planet. Cassini will be making a death dive into the planet on 15 September.

## Uranus 20:30 BST on 22 September



**Constellation**: Pisces
**Magnitude**: 5.7
**AM/PM**: PM

Uranus is still visible through the night. It's not doing anything special or spectacular, just quietly hanging around the southern region of Pisces, minding its own business. With a magnitude of 5.7 it is technically a naked eye planet, if observing from somewhere free of light pollution. On the evening of 6 October, the almost Full Moon will be just less than five degrees away from Uranus, below it.



© NASA

## Moon tour

# Clavius crater

## Find one of the largest lunar impacts, made famous in a science fiction film that helped shape the Space Age

**Top tip!**

Using a lunar filter will help you see features like Clavius during a Full Moon more clearly by reducing glare.

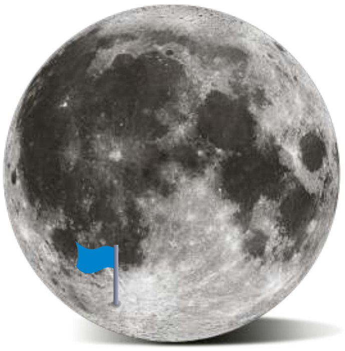
If you're a fan of the classic 1968 science fiction film *2001: A Space Odyssey*, this month's lunar 'celebrity feature' will need no introduction. No, not the bright-rayed crater Tycho, where the alien monolith was unearthed; Tycho is 430 kilometres (267 miles) to the north of our destination. We're going on a tour of the vast crater Clavius.

Clavius is so huge it is easily visible to the naked eye when it lies near the terminator, appearing as an obvious notch between the areas of light and dark. Clavius' diameter of 225 kilometres (140 miles) makes it the third largest crater on the side of the Moon that faces Earth. Binoculars and small telescopes reveal a wealth of detail in and around the crater. The first time you see Clavius with even a little magnification you understand why this four-billion-year-old crater is a favourite object for many lunar observers.

Far away from any of the famous dark seas or historic Apollo landing sites, Clavius lies deep in the rugged and bright lunar southern highlands, 930 kilometres (578 miles) from the Moon's south pole, and is surrounded by countless other craters - large and small - on all sides. Its southerly latitude and proximity to the pole sadly means we don't see Clavius at its majestic best; our view of it is cruelly foreshortened by the curvature of the Moon. However, even a modest pair of binoculars will reveal a lot of fascinating detail in and around it. They will, for example, help you pick out a quartet of smaller craters nestled within Clavius' shallow walls, arranged in a curving chain which arcs upwards from the southern rim to the north. Very conveniently, the craters in the arc get progressively smaller in diameter the farther north they are, making this chain very useful as a test of an instrument's resolving power on a clear night. A pair of binoculars will also show those crater walls themselves bear the scars of two huge ancient impacts: the oval, hummock-floored Rutherford Crater to the south, and the rounder, flatter Proctor crater to the north are both easy to see at just 10x magnification.

It is through a telescope that Clavius truly comes to life. At higher magnification Clavius' floor appears spattered with countless craters - some forming short chains - but you'll need really high magnification to see those. Clavius' northern walls show themselves as extensively terraced and rippled. It's as if a section of that wall collapsed at some point in the distant past, sending a great tsunami of rock and dust sloshing towards the crater floor.

As is the case with all lunar features, you'll get your best views of Clavius when it is near or on the terminator - the line between night and day. Then, the sunlight will be slanting in at an angle, casting long shadows and highlighting the topography of the crater and its surroundings. This month, Clavius will be hidden until 29 September, when the Moon will have just passed First Quarter. On that evening look for the Moon low in the south-east after sunset, just to the left of the planet Saturn. Over the next few evenings Clavius will look better and better, quickly emerging from the gloom of the long lunar night. Fully illuminated by the low Sun its features will really stand out.

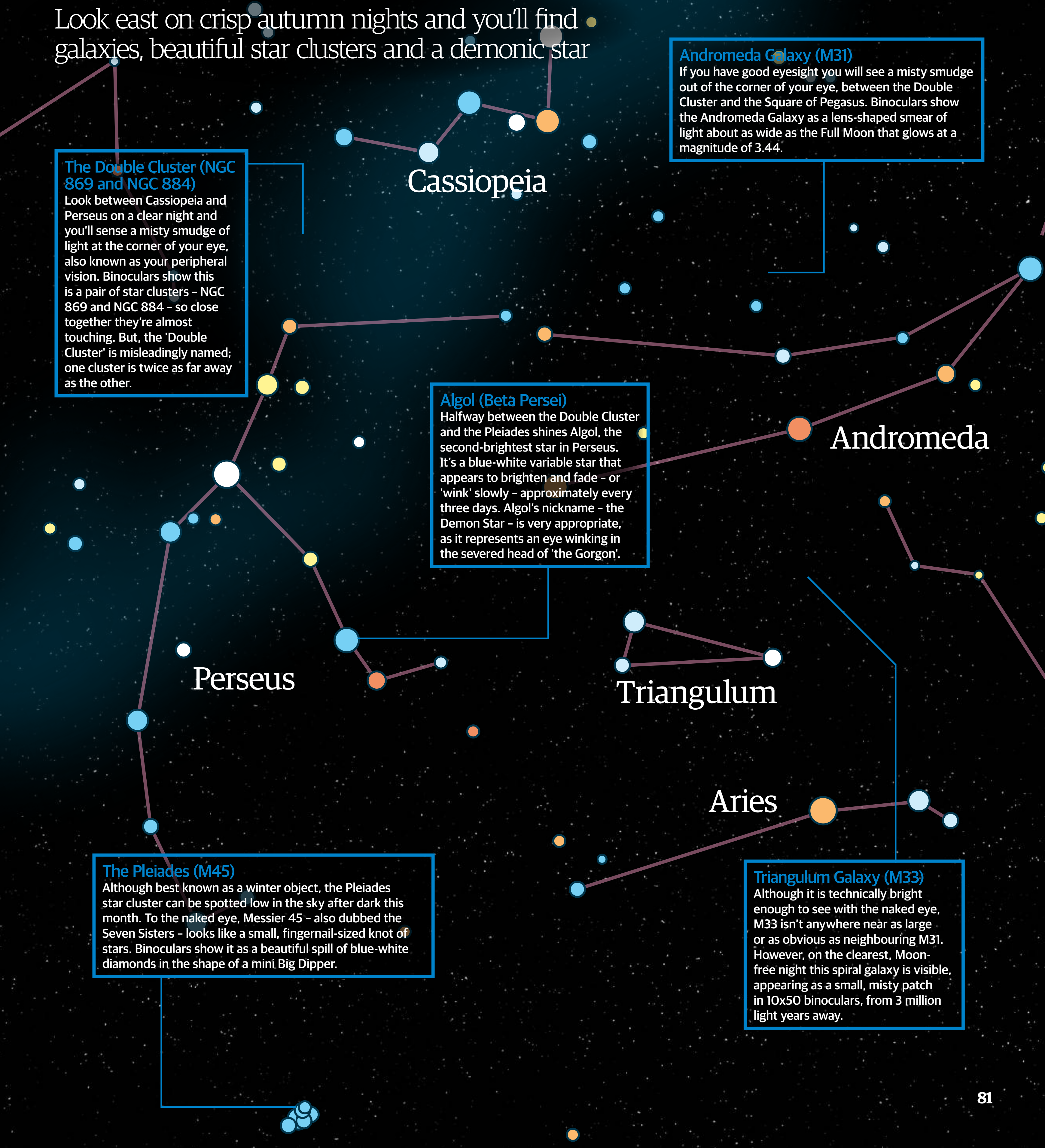


By Full Moon on 5 October Clavius will be past its best, pretty much washed out by the light of the Sun blazing directly above it. The crater vanishes from view on 13 October, darkness crashing over it once more, and won't become visible again until 28 October.

As you look at Clavius through your binoculars or telescope, just think back to that classic scene from *2001* when the shuttle is landing at Clavius Base. Back in 1968, as NASA prepared to land men on the Moon, it seemed possible - if not likely - that there would be such a facility in the year 2001, some 33 years in the future. Today, half a century later in 2017, we're probably no closer to building such a base as we were back in 1968 - a very sobering thought indeed.

# This month's naked eye targets

Look east on crisp autumn nights and you'll find galaxies, beautiful star clusters and a demonic star



### Andromeda Galaxy (M31)

If you have good eyesight you will see a misty smudge out of the corner of your eye, between the Double Cluster and the Square of Pegasus. Binoculars show the Andromeda Galaxy as a lens-shaped smear of light about as wide as the Full Moon that glows at a magnitude of 3.44.

### The Double Cluster (NGC 869 and NGC 884)

Look between Cassiopeia and Perseus on a clear night and you'll sense a misty smudge of light at the corner of your eye, also known as your peripheral vision. Binoculars show this is a pair of star clusters – NGC 869 and NGC 884 – so close together they're almost touching. But, the 'Double Cluster' is misleadingly named; one cluster is twice as far away as the other.

### Algol (Beta Persei)

Halfway between the Double Cluster and the Pleiades shines Algol, the second-brightest star in Perseus. It's a blue-white variable star that appears to brighten and fade – or 'wink' slowly – approximately every three days. Algol's nickname – the Demon Star – is very appropriate, as it represents an eye winking in the severed head of 'the Gorgon'.

### The Pleiades (M45)

Although best known as a winter object, the Pleiades star cluster can be spotted low in the sky after dark this month. To the naked eye, Messier 45 – also dubbed the Seven Sisters – looks like a small, fingernail-sized knot of stars. Binoculars show it as a beautiful spill of blue-white diamonds in the shape of a mini Big Dipper.

### Triangulum Galaxy (M33)

Although it is technically bright enough to see with the naked eye, M33 isn't anywhere near as large or as obvious as neighbouring M31. However, on the clearest, Moon-free night this spiral galaxy is visible, appearing as a small, misty patch in 10x50 binoculars, from 3 million light years away.

## How to...

# Estimate star magnitudes

You have probably noticed that some stars seem brighter than others, which will help you to work out their magnitude

### You'll need:

- ✔ Star chart
- ✔ Red torch
- ✔ Notebook

Every star in the night sky is like our own Sun, although some are larger and others smaller, and all have different brightness. All the stars rest at differing distances, and this too will affect just how bright a star will seem to be. A dim star nearer to us can look brighter than a very bright star a long way away. Add to this that nearly half of all the stars in the sky are variable, that is they can vary in brightness to some degree or other, and it can all seem rather complicated. It is possible, however, to work out just how bright any particular star appears to be, just with a little practice.

Measuring a star's brightness just by eye can be both fun and scientifically useful, but how can this be done? How do you work out just how bright a star is, and can you be sure that it's not going to change in brightness? It is possible to give a quantifiable measurement to the brightness of stars, and this was done many centuries ago by a Greek astronomer named Hipparchus. He classified the visible stars and gave us the 'stellar magnitude' scale. Hipparchus decided that the very brightest stars he could see would be given the designation of magnitude '0' and the very faintest, magnitude '6'. A star of magnitude 5 is 2.5-times brighter than one of magnitude 6, and one of magnitude 4 is 2.5-times brighter than a star of magnitude 5 and so on up the scale. A 1st magnitude star is 100 times brighter than a 6th magnitude one.

The human eye, with a little practice, can be a fairly accurate instrument for measuring a star's brightness. First though, you need to be able to compare a star that you are interested in with one of known brightness. This is where a star chart is invaluable. Most star charts have star magnitudes either written on them, or the brightest stars are represented by a large dot and the faintest by a much smaller dot. A scale is usually given on the edge of the map. Look at a star of known brightness and compare it to the first one you looked at. How bright does it look? After a while you will be making quite accurate estimates. This also can be a useful skill when it comes to estimating the brightness of more transient objects such as meteors and comets.

> "A dim star nearer to us can look brighter than a very bright star a long way away"

## Tips & tricks

**Use a star chart for your initial reference**
Use a star map which has either the stellar magnitudes printed, or the stars brightness shown graphically.

**Wait for your eyes to adjust to the dark**
Always wait for your eyes to fully adapt to the dark before you try to estimate stellar magnitudes.

**Make the most of a red light**
A red torch is essential to allow you to read your star chart without affecting your dark adaption.

**Observe on a Moonless night**
It is much easier to estimate stars' brightness with the Moon out of the way – the less light pollution there is, the better.

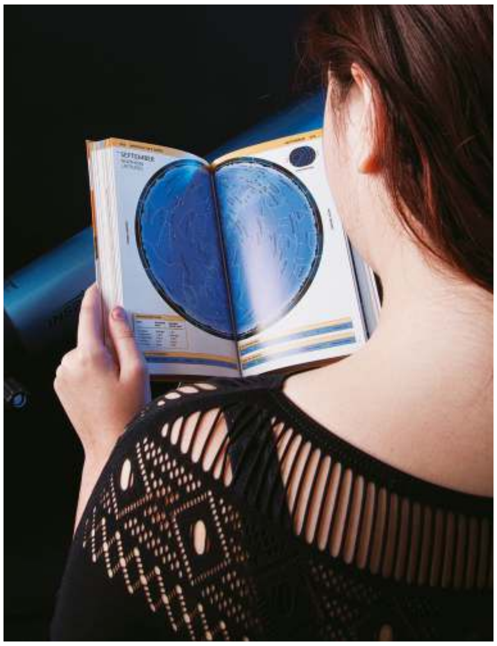
**Avoid city lights**
If possible, you should head to a dark sky site that's free of city lights and any other sources of artificial light pollution.

# Understanding the stars

## Working out the brightness of naked-eye objects can help you to follow the behaviour of variables

There are so many stars which vary in brightness. Some change on a regular or semi-regular basis, and others can seem to vary in a completely haphazard fashion. The amount of variation can change too. When first learning how to do visual estimates of brightness, it's best to start with a few well-known variable stars which vary in a short period, such as the star Algol in Perseus. This changes over a period of two days 20 hours and 49 minutes from magnitude 2.1 to 3.4, so it's easy to track.

Send your photos to
**space@spaceanswers.com**



### 1 Use a star chart for reference

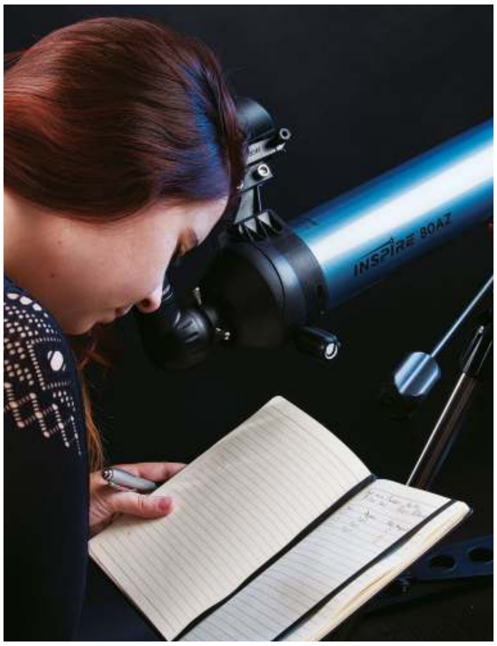
First refer to your sky map and find a star of known fixed brightness. You should examine it carefully in the night sky and use it as a reference point to compare against other objects you find.

### 2 Move to your second target

Next, look at another star of a known but differing brightness nearby and compare the two. Remember, magnitudes are given in numbers - the higher the number, the dimmer the object.

### 3 Locate Algol in Perseus

Take a look at the star Algol (The Demon Star) in Perseus and estimate how bright you think it is. Assign it a magnitude using the stars you observed previously as a reference.



### 4 Use a notebook

Note your estimate down, along with the exact time, date and sky conditions. It's important to have an idea of visibility, since it can throw your estimate off.

### 5 Make multiple observations

Go back out the following night, repeat the previous steps and make a careful note of your estimate. Depending on the conditions, you may have over or underestimated your target's brightness.

### 6 Practice makes perfect!

After a while, you will find that you're getting better in your estimations. It's important to observe for several nights in a row to get the true feel of your target's brightness.

Wizard Nebula (NGC 7380)

## Deep sky challenge

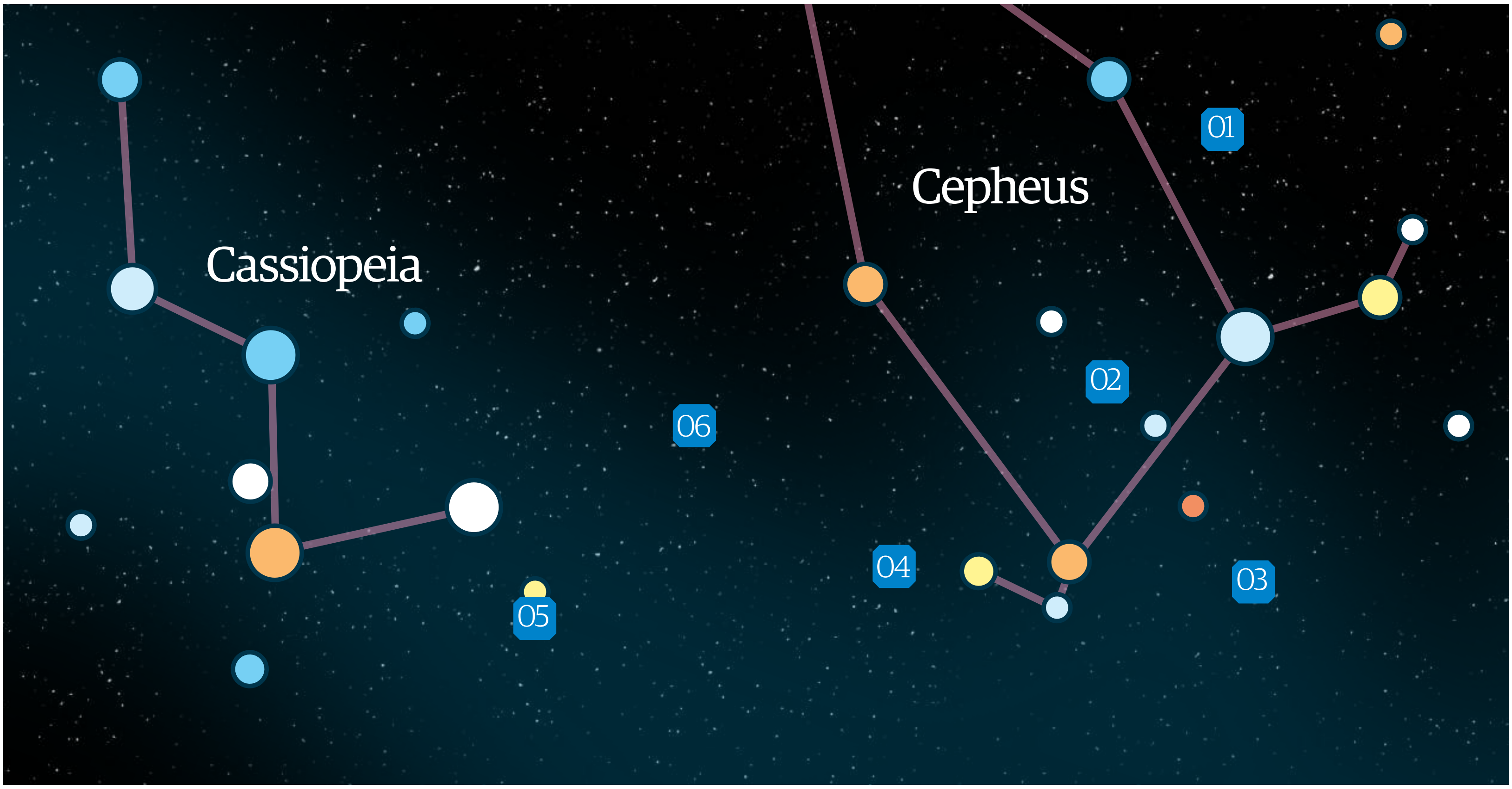
# Treasures of the autumn Milky Way

### Among the richest for deep-sky observers, late September brings star clusters, nebulae and galaxies galore

The Milky Way, that ribbon of light which is part of a spiral arm of our own galaxy, is still well on show during late September and early October. This means that a lot of deep sky objects, which are either embedded in it, or near to it, are also well on display.

High up in the sky from mid-northern latitudes, the constellations of Cepheus (the King) and Cassiopeia (the Seated Queen) can be found sweeping around the north celestial pole throughout the course of the night. The pair of star patterns are full of star clusters and nebulae, easily available to even the most modest of amateur telescopes. Within this region of sky, there are some challenges for those with telescopes with even larger apertures. The Elephant's Trunk Nebula (IC 1396) for example, has a star cluster associated with the nebula, which is relatively easy to see, but it's the surrounding gas and dust that's much more challenging. Whatever you choose to look at, you can enjoy the delights of the autumn skies.

Messier 52



## 1 The Iris Nebula (NGC 7023)

A bright reflection nebula, lit up to magnitude 6.8 by a star cluster at its centre. It requires an instrument with an aperture of at least ten-inches to pick out details beyond a faint, misty patch.

## 2 NGC 7160

A small but attractive open star cluster, NGC 7160 can be picked up under moderate magnification. The cluster is quite sparse, however, its member stars are noticeably bright-white diamonds.

## 3 Elephant's Trunk Nebula (IC 1396)

If you look carefully through your telescope of at least a medium-to-large sized aperture, you can locate a dark, dense globule, known as IC 1396A, which gives the nebula its name.

## 4 The Wizard Nebula (NGC 7380)

Here's another tricky-to-spot nebula with a small star cluster nestled at the centre. In order to pick out the details of the Wizard Nebula, it's likely that you'll need a filter (such as a OIII).

## 5 Caroline's Rose cluster (NGC 7789)

This lovely star cluster does look like a rose seen from above. It's located among the rich starfields of the Milky Way towards Cassiopeia, so will require a trained eye and telescope in order to spot it.

## 6 Messier 52

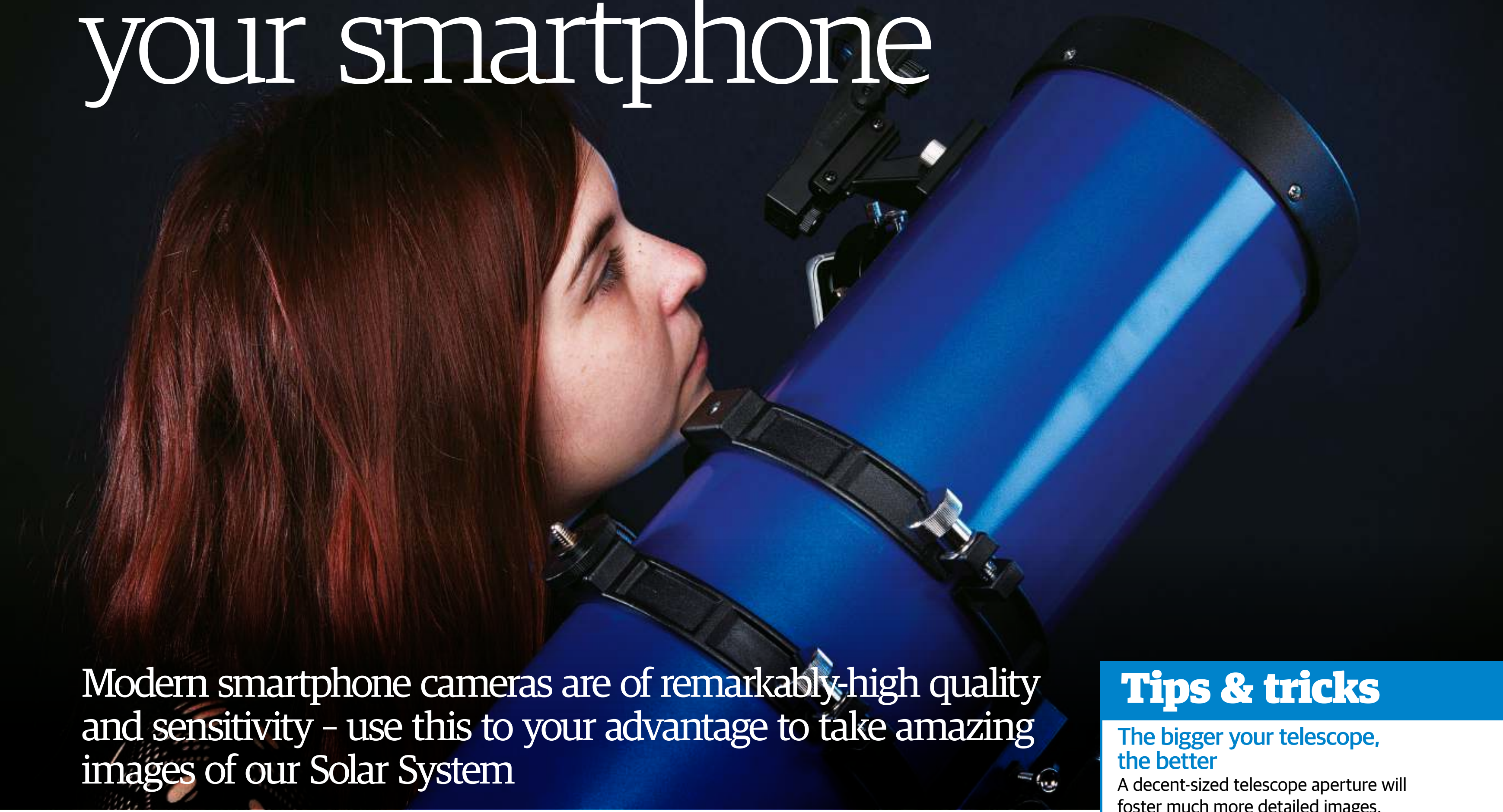
In the constellation of Cassiopeia is this large open star cluster, which is easy to locate in even a small aperture telescope thanks to its magnitude of 5, and its location in the 'W'.

Iris Nebula (NGC 7023)

© Luc Viatour; NASA; Hewholooks

## How to...

# Photograph planets using your smartphone



Modern smartphone cameras are of remarkably-high quality and sensitivity – use this to your advantage to take amazing images of our Solar System

### You'll need:

- ✔ Smartphone
- ✔ Phone bracket
- ✔ A tracking mount
- ✔ At least a telescope with a small aperture

Smartphone cameras are ubiquitous and often of very good quality. They can take both still and video images with good colour balance, and, best of all, they fit in your pocket! All of this makes them a very useful tool to record those amazing views you can get through a telescope of planets such as Jupiter and Saturn.

Most smartphones have HD quality cameras, which means that the images you get are sharp and clear. With this in mind, you can take images through your telescope of the things you see. However, there are one or two provisos and a couple of things you will need to do to get really good-quality pictures.

Firstly, and the most important thing to bear in mind, is that the brighter the image is in the telescope, the better the photo will look. This is because the camera on the phone is designed for daylight use, and is not as sensitive as a purpose-made astronomical imaging camera. That being said, you will still get good shots of bright objects such as the major planets. You can, of course, just hold the smartphone camera lens up to the eyepiece, but this can be tricky, as hands tend to shake, and keeping the camera lens and the telescope lens in line can be awkward. This is where a bracket designed to hold smartphone cameras over the eyepiece can make all the difference. These are relatively inexpensive and will make taking pictures through your telescope a whole lot easier.

The other important piece of equipment you'll need is a tracking mount for your telescope. This can be a simple electric drive, or a computer system that tracks the object of interest. It's surprising how fast an object can disappear from view from a stationary telescope, usually just as you've got everything ready to take the picture! If you haven't got a smartphone bracket, give it a try anyway; you might get a pleasant surprise. Make sure that the focus of the image through the telescope is as sharp as possible, as this will make your pictures look more professional. The key is to keep practising. Your images will improve over time if you keep trying. Have fun and enjoy the results, especially bragging to your friends about how you took the pictures with your phone camera.

## Tips & tricks

### The bigger your telescope, the better

A decent-sized telescope aperture will foster much more detailed images. However, it is still possible to get good pictures through even a small scope.

### Use the centre of your field of view

Ensuring that your target planet is at the centre of your field of view will provide better results – particularly if your instrument suffers from coma at the edge of the objective lens.

### Track your planet

Make sure the drive motor is working, and allow it to settle if you've just switched it on. Tracking will ensure that the planet is always centred.

### Go for a low-power eyepiece

Avoid using eyepieces that provide high magnification. A lower power gives a brighter image, which makes for a better image with your phone camera.

### Ensure your view is focussed

You should make sure the focus through the telescope is a sharp as possible, otherwise your shot will be blurred with next to no detail.

# Planning for superb astrophotography shots

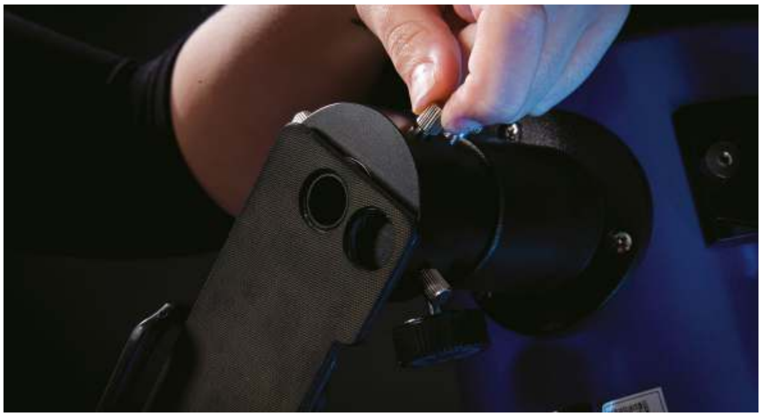
## Being prepared and following a methodical approach is key to imaging the Solar System

If you are methodical in your approach you will get some remarkably good results quite quickly. A bracket, which holds the phone firmly in place directly above the eyepiece, will improve your chances of getting really clear images, so use one if you can. Try to avoid holding onto the camera when you are taking the pictures, as this tends to introduce vibrations into the telescope and camera, which will blur your images. Practise often and you will quickly see improvement in the quality of your shots.

Send your photos to
**space@spaceanswers.com**

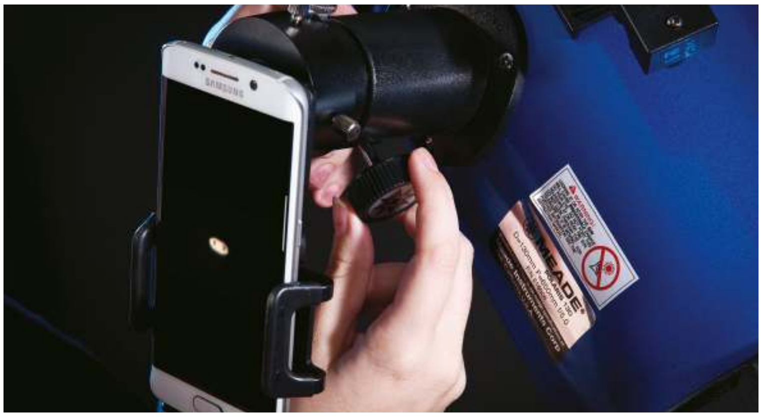
1 **Decide on a planet to image**
Find and centre the planet you wish to image through your telescope eyepiece. This month, Venus and Saturn are good targets for capturing detail.

2 **Make the most of your telescope's motor**
Ensure that your telescope mount's drive system is on and operating. Motors are useful for tracking the planet through the course of the night.



3 **Fix a smartphone bracket to your eyepiece**
Make sure that the camera bracket, if you are using one, is in place and secure. There are dedicated brackets for your telescope for steady astroimaging.

4 **Make sure you have a good view**
Check that you have a decent image of the planet on your phone's screen. Try to get it in focus as much as you can using your telescope's focuser.



5 **Ensure that your chosen planet is centred**
Usually, if your image is in the centre of the field of view, then it's likely to align in your camera's view. Make small adjustments if necessary.

6 **Take as many images as possible**
One of the keys of astroimaging is to take as many images as you can. You'll notice that some shots are better than others.

# The Northern Hemisphere

Aquarius and Pegasus grace the skies of late September and into October, marking the darker evenings

With the Sun setting not long after 19:00pm (BST) this month, rich pickings can be had by those with even the most modest observing equipment. The end of September affords the chance to catch the likes of Cygnus (the Swan) and Capricornus (the Sea Goat) and their wealth of deep-sky objects before they become unobservable in October.

Look out for the 'square' of Pegasus (the Winged Horse) rising in the west while Cepheus (the King) appears in the northwest. In both constellations, a selection of binary stars can be split using small telescopes. Aquarius (the Water Bearer), Taurus (the Bull) and Orion (the Hunter) offer globular and open clusters along with glowing star-forming regions, which are a breeze to pick up through binoculars as well as the naked eye under a night sky untouched by light pollution.

## Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

## Magnitudes

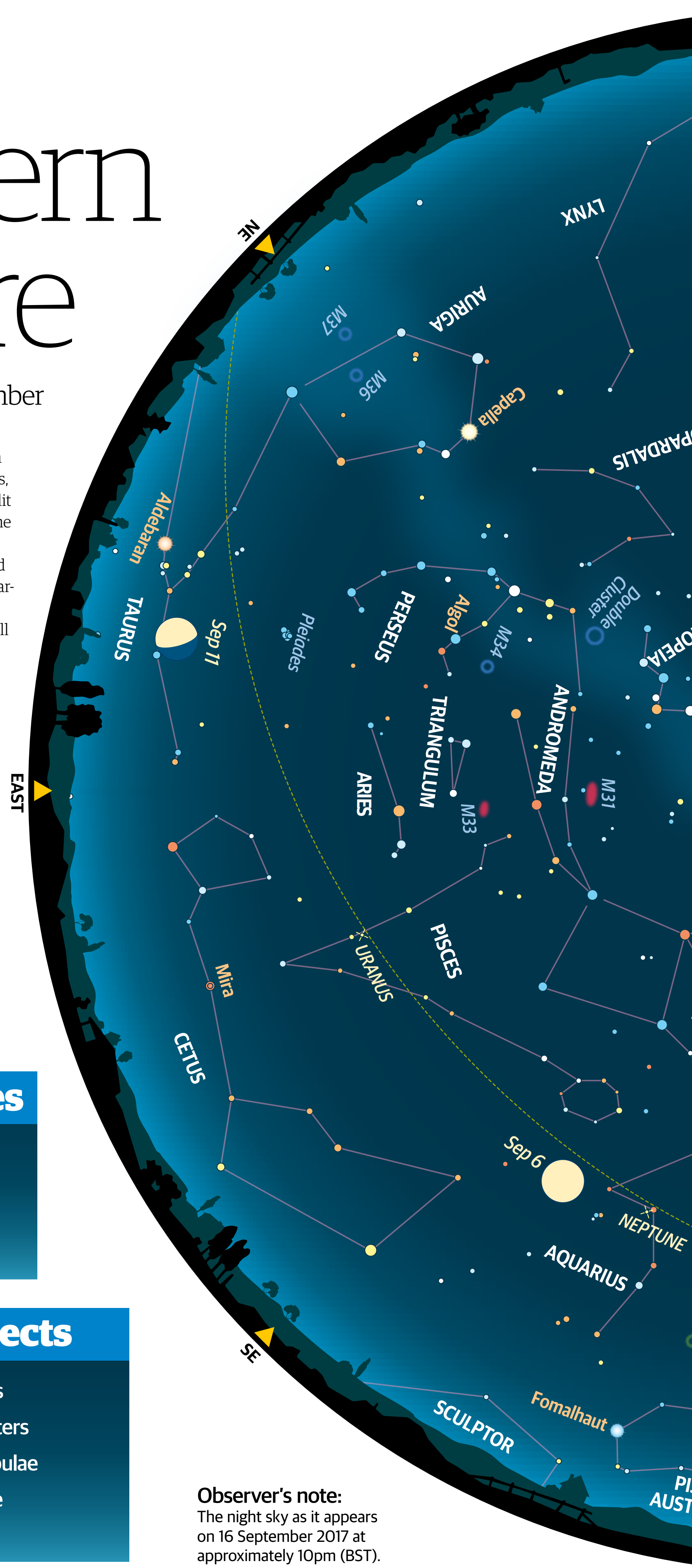
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- ● 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- • 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ◉ Variable star

## Spectral types

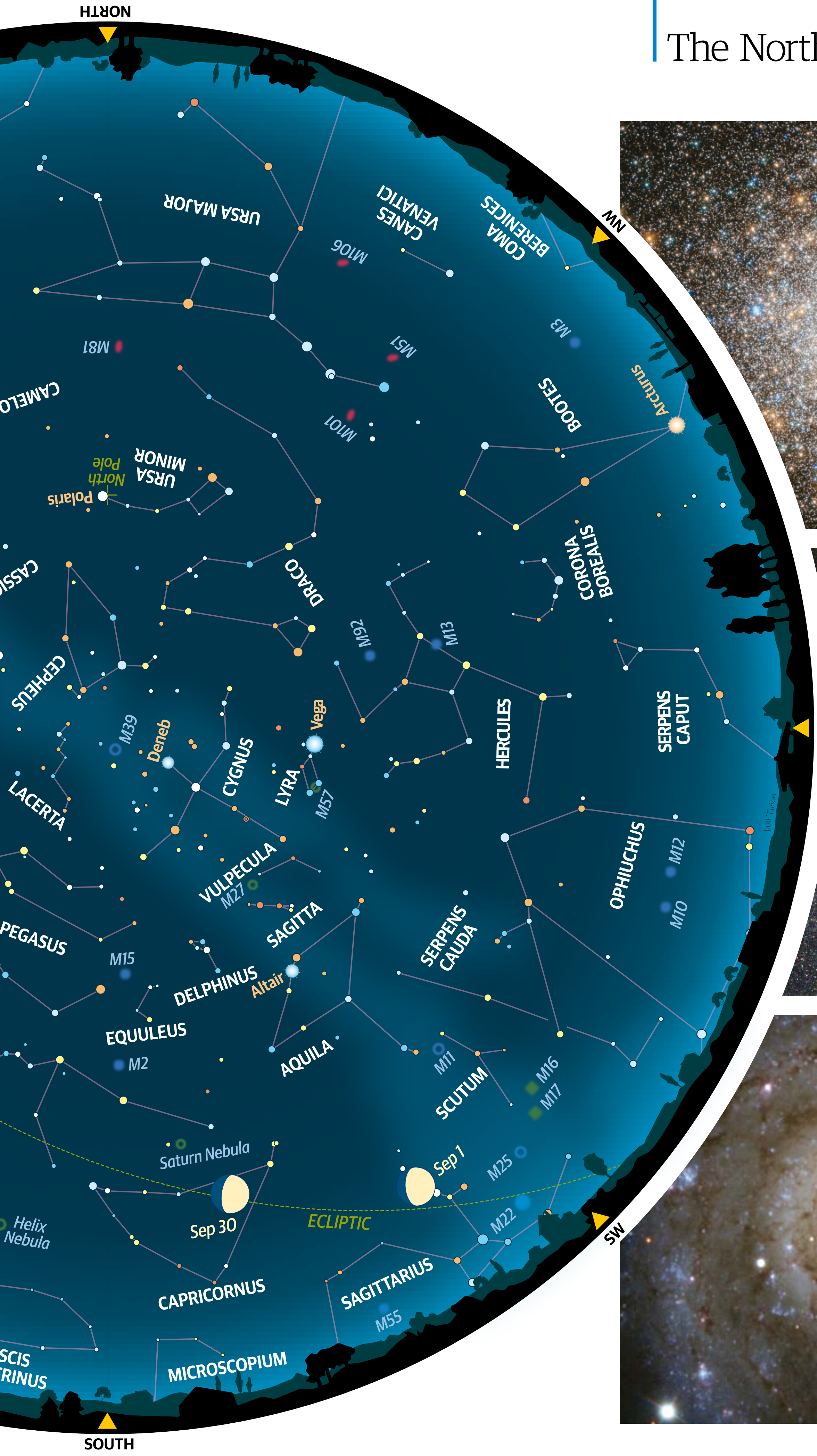
- ● O-B
- ● A
- ● F
- ● G
- ● K
- ● M

## Deep-sky objects

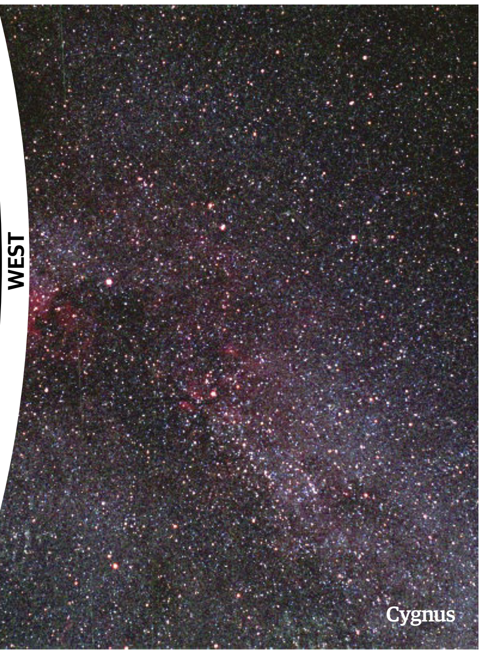
- ○ Open star clusters
- ● Globular star clusters
- ■ Bright diffuse nebulae
- ◎ Planetary nebulae
- ⬮ Galaxies



**Observer's note:**
The night sky as it appears on 16 September 2017 at approximately 10pm (BST).



Messier 15

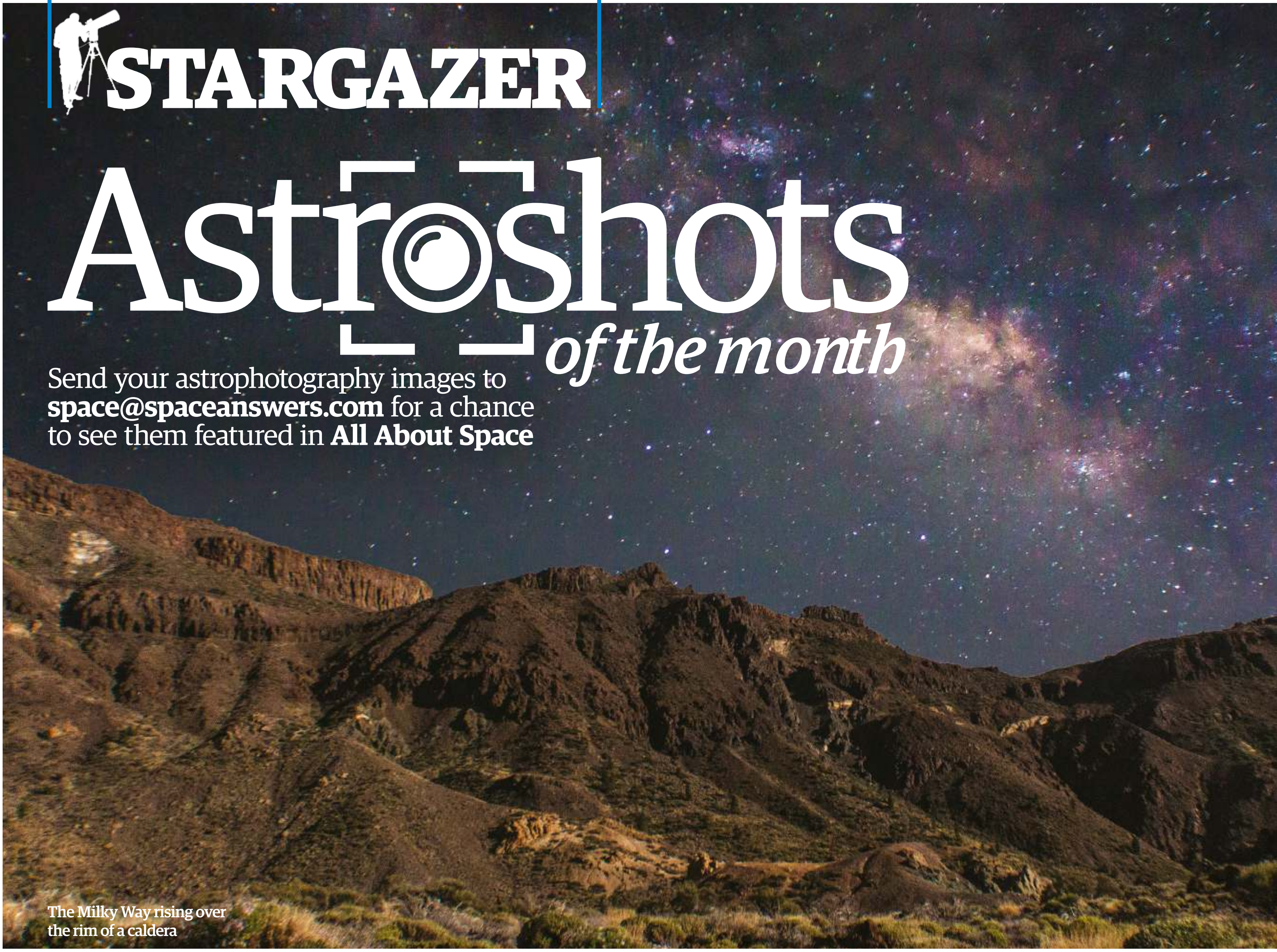

Cygnus

Messier 74

© Wil Tirion; ESA; NASA; ESO/PESSTO/S. Smartt; Ole Nielsen

# Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

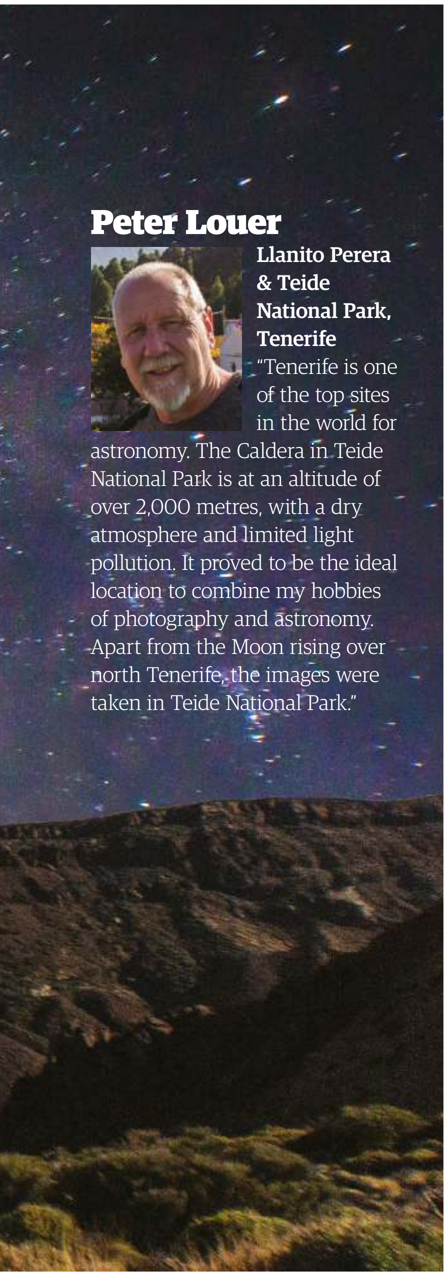


The Milky Way rising over the rim of a caldera

The Milky Way and Saturn

Nightfall in Teide National Park

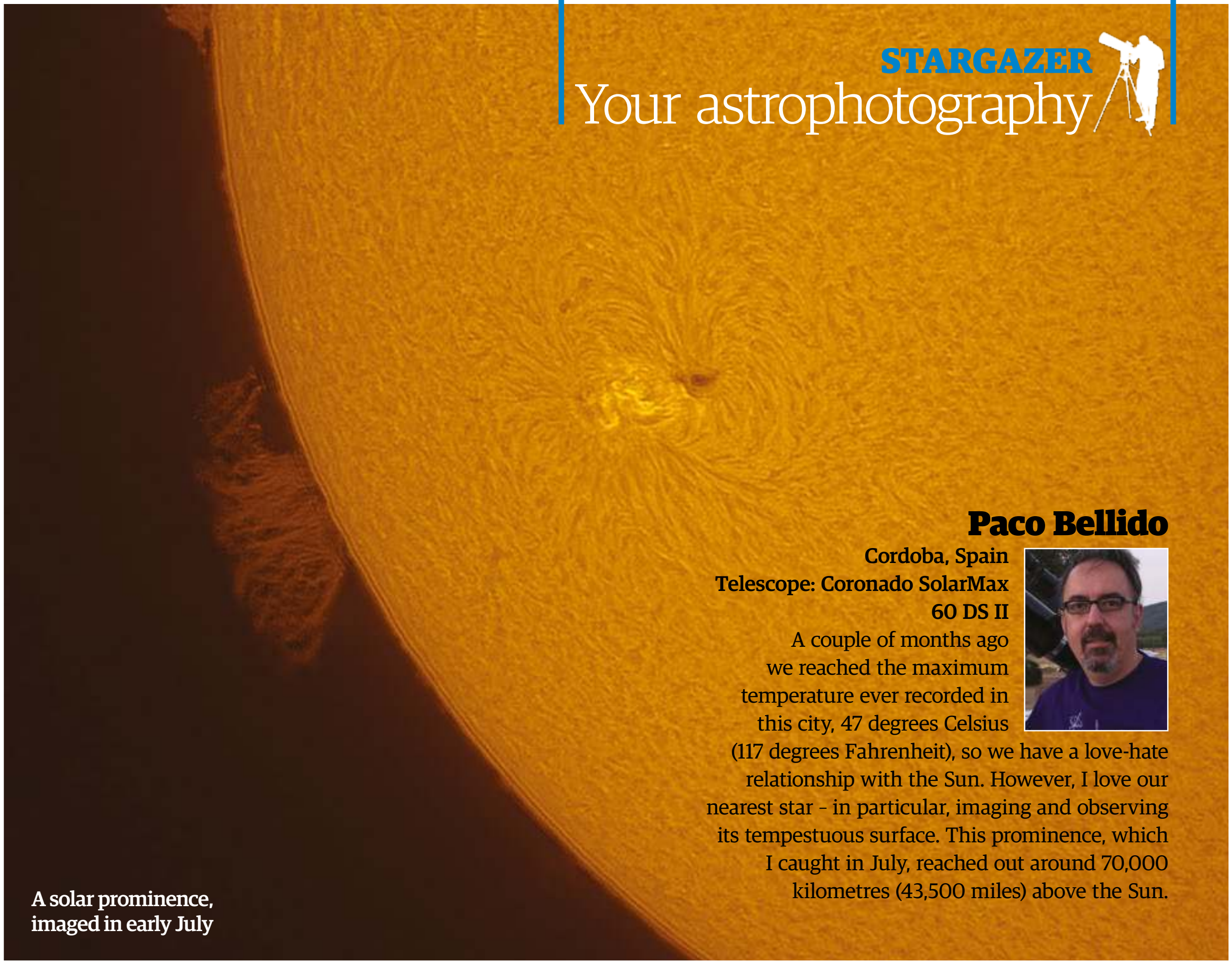
Full Moon rising over north Tenerife



## Peter Louer

**Llanito Perera & Teide National Park, Tenerife**

"Tenerife is one of the top sites in the world for astronomy. The Caldera in Teide National Park is at an altitude of over 2,000 metres, with a dry atmosphere and limited light pollution. It proved to be the ideal location to combine my hobbies of photography and astronomy. Apart from the Moon rising over north Tenerife, the images were taken in Teide National Park."

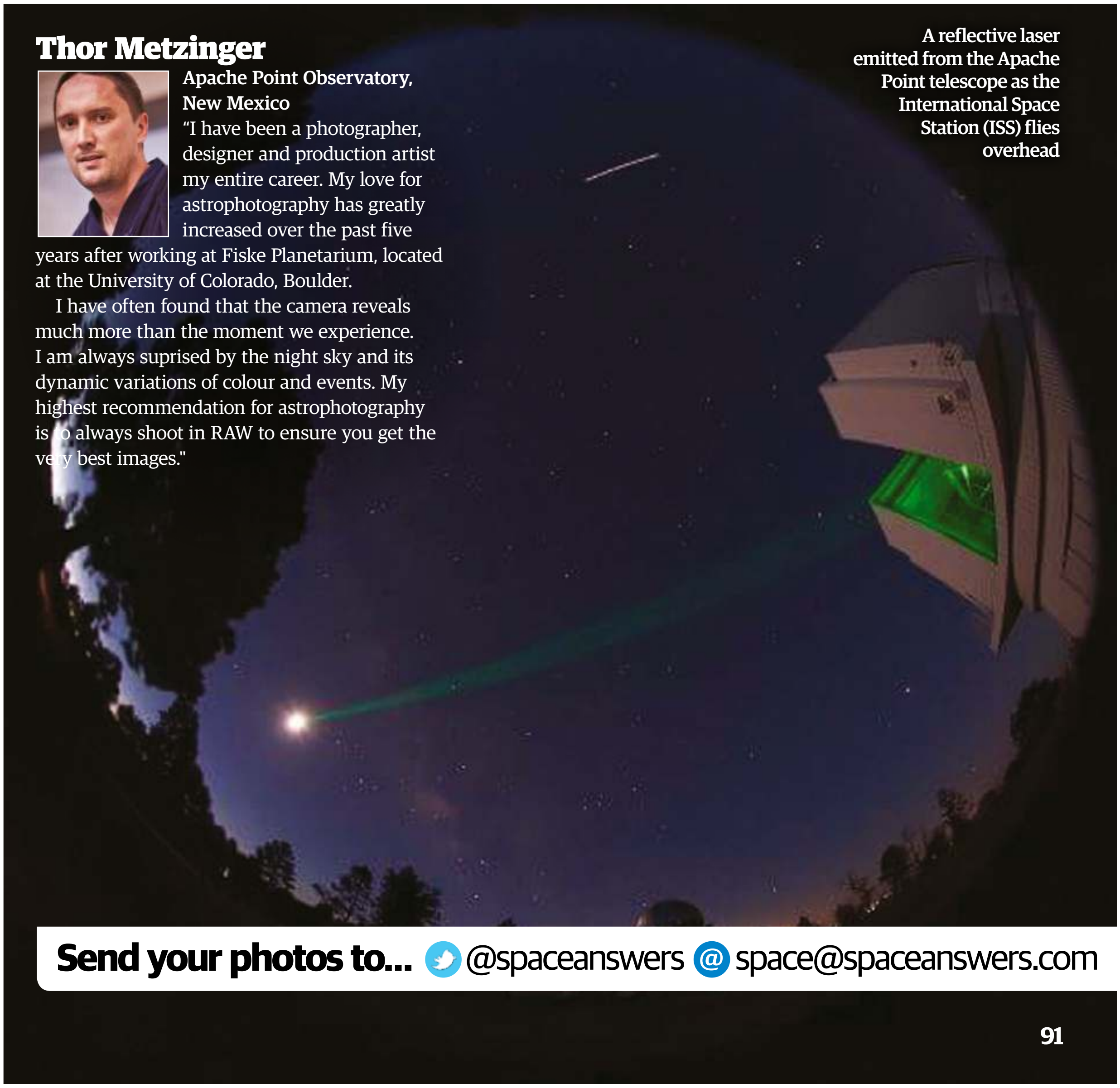


A solar prominence, imaged in early July

## Paco Bellido

**Cordoba, Spain**
**Telescope: Coronado SolarMax 60 DS II**

A couple of months ago we reached the maximum temperature ever recorded in this city, 47 degrees Celsius (117 degrees Fahrenheit), so we have a love-hate relationship with the Sun. However, I love our nearest star - in particular, imaging and observing its tempestuous surface. This prominence, which I caught in July, reached out around 70,000 kilometres (43,500 miles) above the Sun.



A reflective laser emitted from the Apache Point telescope as the International Space Station (ISS) flies overhead

## Thor Metzinger

**Apache Point Observatory, New Mexico**

"I have been a photographer, designer and production artist my entire career. My love for astrophotography has greatly increased over the past five years after working at Fiske Planetarium, located at the University of Colorado, Boulder.

I have often found that the camera reveals much more than the moment we experience. I am always suprised by the night sky and its dynamic variations of colour and events. My highest recommendation for astrophotography is to always shoot in RAW to ensure you get the very best images."

**Send your photos to...** @spaceanswers space@spaceanswers.com

# Celestron Inspire 80AZ refractor

## The second largest telescope of a new range proves to be a reliable starter instrument at a budget price

The Celestron Inspire 80AZ is the new and improved member of the Inspire family. Not only have its superior optics and accessories increased its observational capabilities, but it's also incredibly easy to transport and assemble wherever needed, since it promotes a light and effortless set up. This refractor is not only ideal for dipping your toes into observing bright deep-sky objects, its optical system provides decent views of the Solar System.

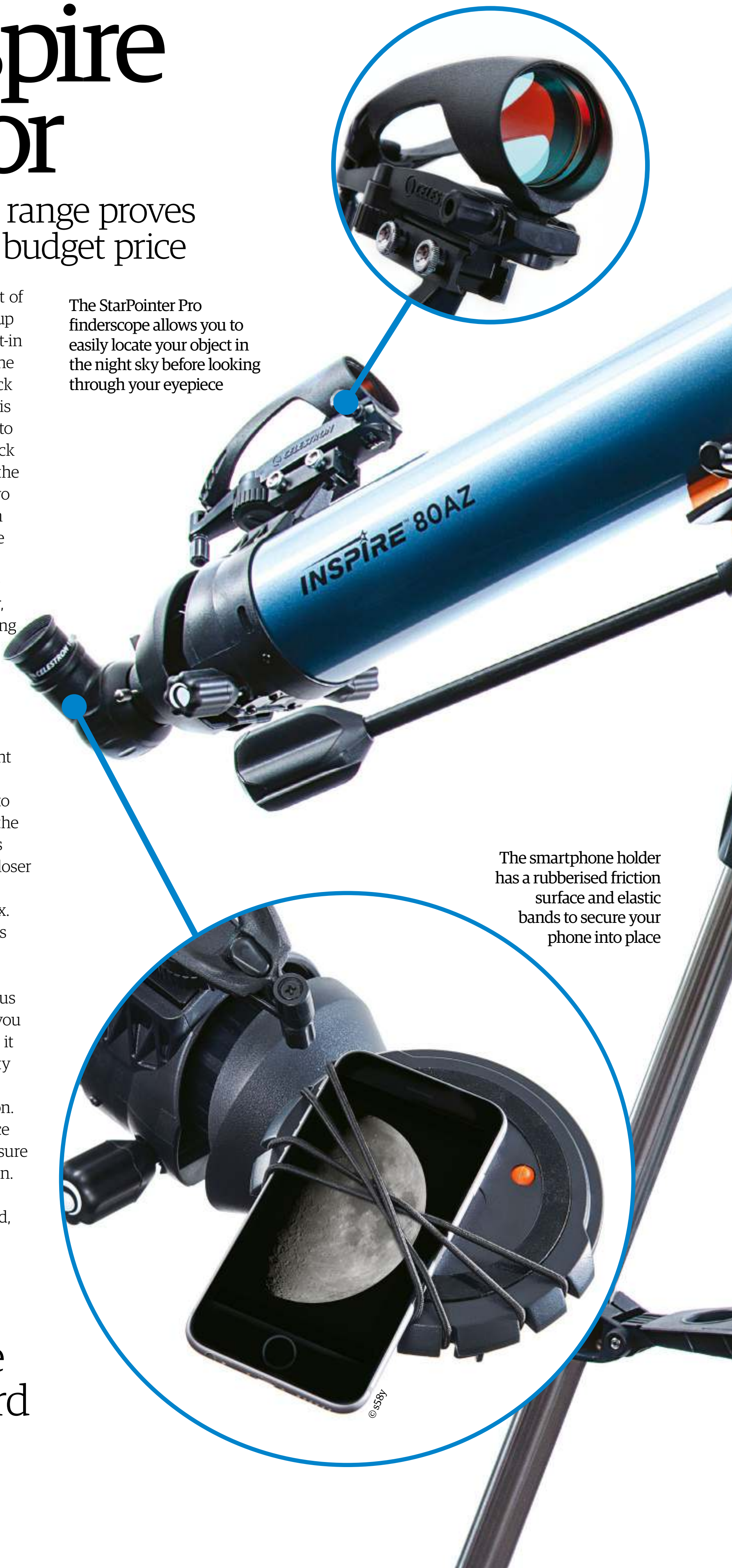
The refractor telescope comes with a 90-degree diagonal (1.25"), a pair of 20mm and 10mm Kellner eyepieces and a StarPointer Pro finderscope, which provides you with everthing you need to start your observations of the cosmos. There are also a few other items that come with the kit that are rarely included with a beginner's telescope, such as a telescope cap that doubles as a smartphone holder as well as a detachable LED red flashlight. This red flashlight can either be attached to the mount to shine on the tripod tray, but can also be detached, making it useful piece of kit to have in your observing arsenal. The fact that the flashlight is red is important for your night vision, since your eyes normally take between 20 to 30 minutes to adjust to the dark. With the Inspire 80AZ comes a download code for Celestron's 'Starry Night' astronomy software. This software will allow you to plan your observing sessions, but because this telescope doesn't have a computerised mount, it's not possible to make the most of the software using the 'Go-To' facility. It could be useful if you already have a computerised Celestron telescope, or are looking to upgrade to one sometime in the future.

The assembly of this telescope is a fantastically straightforward aspect of this equipment. You simply open up the tripod legs and secure the built-in accessory tray's position, then fit the telescope tube into the dovetail lock on the alt-azimuth mount. As this is a beginner's telescope, you'll have to manually slew the telescope to track a deep sky object, which requires the simultaneous movement of the two axes. Tracking smaller targets with this scope can be a challenge since it requires a delicate, steady hand - something that can be a challenge to achieve for a beginner. However, practise does make perfect, meaning that the user should be able to overcome this for a satisifying observing experience.

One of our review sessions was focused on the observing of the Moon, as it was roughly 90 per cent luminosity, so the majority of the lunar surface was available for us to see. The 20mm eyepiece showed the overall surface of the Moon with is 45x magnification. If you want a closer look, you'll need to use the 10mm eyepiece for a magnification of 90x. Due to the impressive optics of this telescope, we were able to deduce the most famous lunar landmarks, including the Tycho and Copernicus crater and the grey lunar mare. If you come across this view in your use, it will serve as a fantastic opportunity to utilise the smartphone holder and acquire a snapshot of the Moon. Fortunately, it's easy to attach, since there are a few elastic bands to ensure that the phone is fixed into position. Remember, if there is an option to change your screen colour to red, this will greatly benefit your night vision.

A later observing session, saw us treated to a New Moon phase,

> "The assembly of this telescope is a fantastically straightforward aspect of this equipment"



The StarPointer Pro finderscope allows you to easily locate your object in the night sky before looking through your eyepiece

The smartphone holder has a rubberised friction surface and elastic bands to secure your phone into place

© s8y

The LED red flashlight can be fixed into the mount, or you can detach it for external use

> “The optics are to a good enough standard to reveal some enjoyable objects”

affording us the opportunity to seek out and test the Inspire 80AZ mettle on deep-sky objects. Having just missed our opportunity to observe Jupiter, we turned our attention to the ringed gas giant Saturn, which shone brightly at an impressive magnitude of 0.36. Although its luminosity made the planet easy to navigate to, the angular size of Saturn was considered too small to fully appreciate its beauty, even with the 10mm eyepiece. Refractor telescopes commonly produce slightly blurry views, due to lense aberration, which created a challenge in resolving Saturn and its ring system. We advise experimenting with a selection of eyepieces, which you'll need to buy separately either from Celestron or an independent telescope retailer.

The 20mm eyepiece provides the much wider field of view out of the two eyepieces, which means you are able to search a larger potion of the sky. This is not best suited for the Solar System planets, and we discovered it to be much more useful for the bright deep-sky objects. We decided to try and look at our neighbouring galaxy, Andromeda - designated Messier 31 - which is much fainter than a Full Moon, but six times larger on the sky. The light gathering capabilities of this telescope passed the test, as it revealed the oval of light with the largest concentration luminence at the core of the spiral galaxy. The 20mm managed to display an adequate view with the lower magnification. With the favoured winter months on the horizon, we will have the ‘old faithfuls’, such as the Orion Nebula (M42) and Pleiades star cluster (M45), back in the Northern Hemisphere. With the arrival of these, it will provide a much brighter collection of deep-sky objects to observe.

The Celestron Inspire 80AZ is an excellent telescope for a beginner; its easiness to carry and set up is the key selling point, and the optics are to a good enough standard to reveal some enjoyable targets in the night sky. The detachable LED red light and the smartphone holder are features that do not usually come with many beginner scopes, but are indeed very useful extras for preserving night vision and getting started in basic astrophotography.

## Telescope advice

**Cost:** £179.00 (approx $231)
**From:** Tring Astronomy Centre
**Type:** Refractor
**Aperture:** 3.15”
**Focal length:** 34.43”

## Best for...

- Beginners
- Medium budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects
- Basic astrophotography

# WIN!

# SKY-WATCHER EVOSTAR-90

## Begin your tour of the night sky with this lightweight, yet sturdy, refractor

**WORTH £259**

It has never been easier to grab a telescope and head outside to peer deep into the cosmos. By winning the Sky-Watcher Evostar-90, courtesy of Optical Vision Limited, you can have exactly that experience. Once you've carried this lightweight refractor to your required location, it takes a mere few minutes to begin observing what the universe has to offer.

This telescope will not only let you see fantastic detail on the Moon, but it can also resolve other Solar System objects, including Jupiter and its Galilean moons. Look deeper into space, and you'll be able to see a variety of deep-sky objects that have kept astronomers amazed time and time again. If you're keen to take part in daytime observing, the Evostar-90 is suitable for terrestrial viewing and sights of the solar surface with the simple attachment of a solar filter.

Available with this portable and easy-to-use telescope are two eyepieces (10mm and 25mm), a finderscope, an accessory tray, multi-coated objective lenses and a 90-degree mirror star diagonal for comfortable and superior observations.

To be in with a chance of winning, all you have to do is answer this question:

**What is the third largest moon in the Solar System?**

**A: Triton B: Callisto C: Ganymede**

Enter via email at
**space@spaceanswers.com** or by post to
**All About Space competitions, Richmond House, 33 Richmond Hill, Bournemouth, BH2 6EZ**

Visit the website for full terms and conditions at **www.spaceanswers.com/competitions**

**Courtesy of**

OVL

Sky-Watcher®
Be amazed.

**Congratulations to Robert Ortiz, who is the winner of the Altair GPCAM2 IMX224 colour camera**

# LEARN TO INSPIRE

www.dphotographer.co.uk

FREE RETOUCHING VIDEOS
EXPERT EDITING GUIDES TO IMPROVE YOUR SKILLS
50 MEGAPIXEL SHOOTOUT
Digital Photographer
Practical advice for enthusiasts and pros
LEARN TO USE
FLASH on LOCATION
Master essential skills for capturing polished portraits
HARNESS THE POWER OF PIXELS
Shoot for the edit with advanced pro advice
CANON EOS 77D TESTED AND RATED
Create AERIAL ABSTRACTS
Work with a drone
Discover DRAMATIC WILDLIFE
ADJUST COLOUR IN LIGHTROOM
FUJIFILM X100F ON TEST

EVERY ISSUE • FREE RESOURCE DOWNLOAD

# Digital Photographer™

Available from all good newsagents and supermarkets

## ON SALE NOW

**Flash on location > The power of pixels > Discover dramatic wildlife**

LANDSCAPE TIPS

SHOOTING ADVICE

WILDLIFE PHOTOS

PORTRAIT GUIDES

CAMERA REVIEWS

# BUY YOUR ISSUE TODAY

Print edition available at www.myfavouritemagazines.co.uk
Digital edition available for iOS and Android

Available on the following platforms

Print Tablet Phone Desktop

facebook.com/DigitalPhotographerUK twitter.com/DPhotographer

# In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike

## Model Solar System Orrery

**Cost:** £20.90 (approx. $27.00) **From:** Rapid Education / Cochranes of Oxford Ltd

This Solar System Orrery is a very basic representation of our Solar System, consisting of different coloured balls rotating around a central orange 'Sun' that lights up, that's useful for educational purposes. Some of the things that this model can be used for are, demonstrating how an eclipse occurs, the retrograde motion of Mars in the night sky or even just for explaining the structure of the Solar System to young, budding observers of the universe.

However, we feel that this product is quite overpriced, based on its capabilities. For example, when the AA batteries are slotted in, the 'Sun' is only - and quite simplistically - lit up. The scale-model, plastic planets - as far out as Neptune - as well as the Moon are moved by hand. The orrery is 10 centimetres tall, with the largest orbit stretching out to 38 centimetres. Sadly, the 'planets' look nothing like the real thing.

If you're looking for a sophisticated orrery, then look elsewhere. However, if you are keen on teaching youngsters below the age of five about the motions of the Solar System, it could prove useful.

## Software WorldWide Telescope v5.5

**Cost:** Free **From:** www.worldwidetelescope.org

The WorldWide Telescope is an exciting, extensive and impressive observatory you can control with the click of a mouse and where you can observe the wonders of the cosmos using ground- and space-based telescope observations. You can browse the constellations in the night sky, and then zoom in to find some fantastic spiral galaxies, among many other deep-sky objects. We were particularly impressed with the sophisticated option for a 'Guided Tour', where you don't need to slew or click your way through the cosmos, which doesn't just provide entertainment, but is packed full of astronomical gems of information. Created with Microsoft's Visual Experience Engine by the American Astronomical Society, the interface is appealing and easy to use, which makes the experience all the more enjoyable. If the more advanced astronomer fancies something more challenging, they can observe the sky in different wavelengths as well as the Cosmic Microwave Background, the relic radiation left over from the Big Bang.

This software is only available on Windows 7 and newer versions, with a browser-based edition available on other systems. The installation is incredibly straightforward and for no cost at all, it's a must-have!

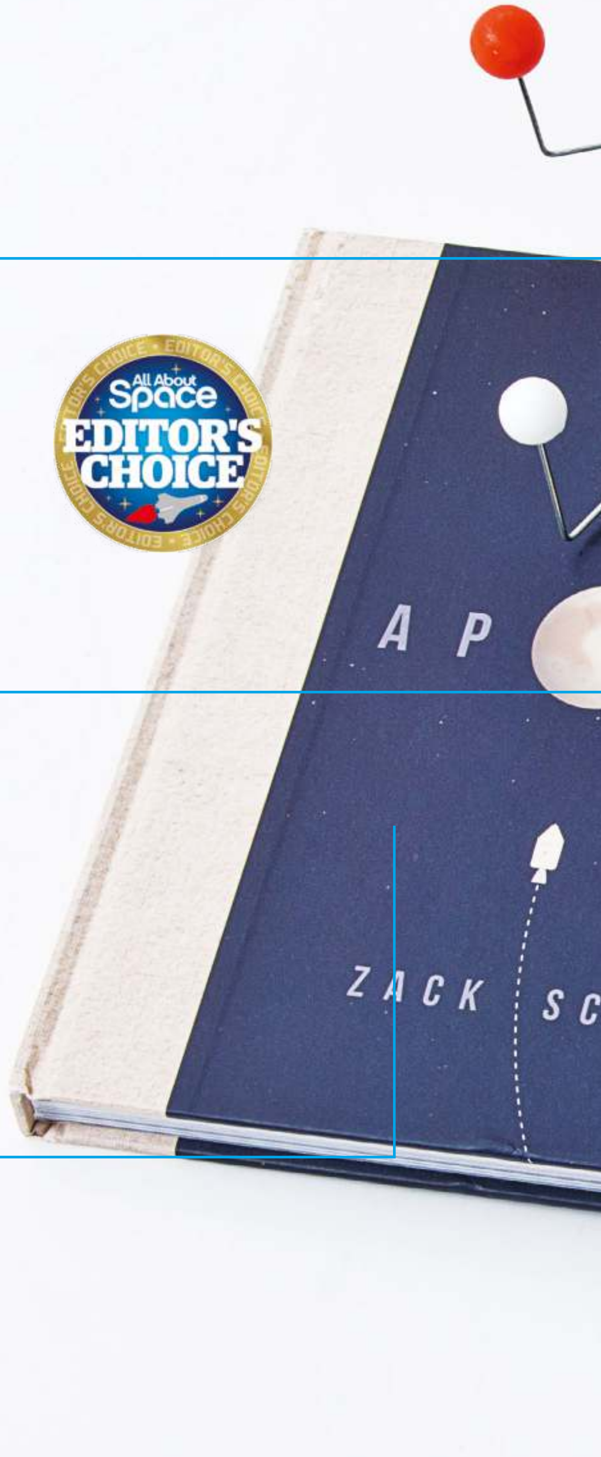
## Book Apollo

**Cost:** £20.00 (approx. $25.90) **Publisher:** Wildfire (available September 2017)

Everything you need to know about the Apollo missions is wonderfully presented in this 160-page enchiridion, available this month from publisher Wildfire.

Written by Zack Scott, a previous Royal Air Force pilot, a graduate of graphic design and an obvious fan of the Apollo space exploration missions, Scott - using his graphic design knowledge - has created a fantastic culmination of infographics and labelled diagrams that brings the moon missions to life. It begins by detailing all the machinery that made the missions possible, then the mission profiles of Apollo 1 to 17, including Apollo-Soyuz and Skylab. It then moves onto the profiles of the twelve men to walk on the Moon. A slight niggle, however - it is a shame that the other famous astronauts were not mentioned, such as the ones who stayed in the Command/Service Module.

The book finishes with a series of well-presented infographics, which really emphasise the colossal success of the Apollo program. As the layout of the book includes many images and relatively small amounts of text, it seems that *Apollo* is suited to a younger target audience, but this isn't to say that an adult who enjoys infographics won't learn a thing or two.



## App Solar Walk v2.4.2

**Cost:** $4.99 (approx. £3.86) **From:** Vito Technology

If you're looking for a fascinating 3D model of the Solar System on your smartphone, then look no further.

In terms of graphic design and user interface, the *Solar Walk* app is among the best we have used. By being able to jump from planets, to moons, to stars, you will be engrossed by what this app has to offer.

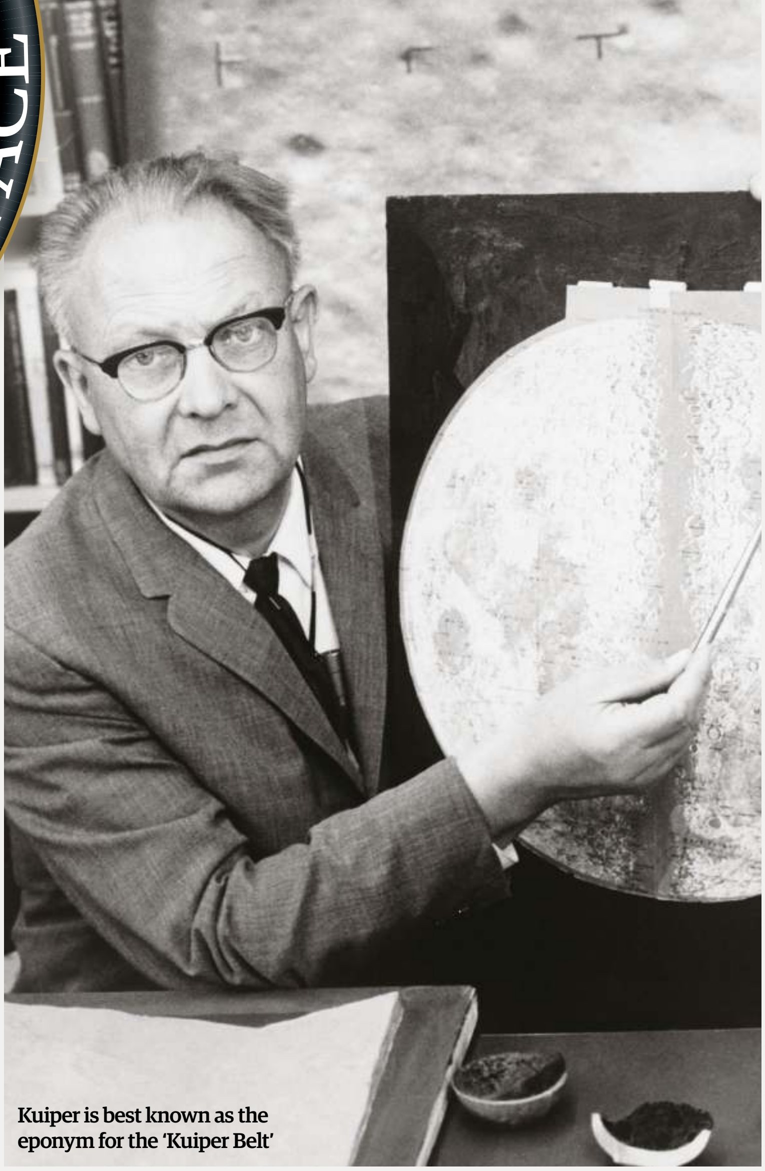
Suitable for astronomers of all ages, this app is not only packed full of essential information, it's also presented in an extremely inviting way. You will be able to focus on each of the Solar System planets, as well as the other moons and dwarf planets that inhabit the solar neighbourhood. Beyond this, you can also check out some well-known stars outside of our Solar System, including Sirius, Procyon and Vega.

You can pay for delightful extras, adding the option to view the high-resolution images of Earth, the Moon, Mars and Venus, satellites, rovers, Apollo landings and even brief videos of eclipses, orbits, amongst other features. Overall, this is a highly-recommended app, capable of keeping you entertained while you learn about the wonders of the Solar System and beyond. The graphics are the main selling point, but it became quickly apparent how creative and clever *Solar Walk* is.

American Astronomical Society
WorldWide Telescope
Welcome to the WorldWide Telescope Web Client
MacBook Air
LLO
OTT
2013.12.06 14:47
Venus
Saturn
SAMSUNG

# Gerard Kuiper

## This determined astronomer changed our understanding of the Solar System



Kuiper is best known as the eponym for the 'Kuiper Belt'

© Everett Collection Historical / Alamy Stock Photo

Growing up as a village boy in northern Holland, Gerard Kuiper eventually ended up as arguably one of the fathers of modern planetary science. The American-Dutch astronomer has many achievements to his name. The most literal and notable of these achievements is the proposal of the 'Kuiper Belt' - named after him upon discovery. Although he's best known for his belt, he also discovered and predicted many aspects of our Solar System that altered the planetary sciences.

He was born in Tuitjenhorn, Holland on 7 December 1905, the son of a tailor. He possessed extraordinary sight - Kuiper could apparently decipher the stars to a magnitude of 7.5! This is something that could have ignited his love of astronomy, seeing more stars than anyone else and wanting to see even more. Kuiper eventually went on to gain a Bachelor of Science degree in Astronomy from Leiden University in 1927, followed by a doctoral thesis on binary stars in 1933.

This began a fruitful career for Kuiper, who worked for many observatories, beginning with the Lick Observatory. Following Lick was Harvard College Observatory, and then Yerkes Observatory, where he initiated the Yerkes-McDonald asteroid survey (1950-1952). All this experience and passion culminated in a determined astronomer dedicated to understanding the planetary science of our Solar System. This led to revolutionary discoveries and theories about our Solar System, such as the discovery of Uranus' moon Miranda, the correct prediction that carbon dioxide is a major component of Mars' atmosphere, and again correctly predicting that Saturn's rings are made up of ice. This further led to him discovering Neptune's irregular moon Nereid in 1949, as well as proposing a promising theory of the origin of the planets - he suspected that a large cloud of gas around the Sun eventually condensed into the worlds of Solar System.

In 1951, Kuiper made his most famous proposal: that beyond the orbit of Neptune is a disk-shaped region filled with copious amounts of minor planets which would wander into the inner Solar System, creating comets. This region has henceforth been known as the 'Kuiper Belt', but it wasn't actually proven until 1992 when the first Kuiper Belt Object (KBO) was observed.

He went on to suggest that Mars' poles weren't frozen carbon dioxide, and they were, in fact, frozen water in 1956. In the 1960s, Kuiper was also involved in the Apollo missions, helping to identify potential safe landing sites. Without even stepping on the Moon, he predicted the surface felt like walking on 'crunchy snow'. The astronaut Neil Armstrong then proved this when he became the first man to walk on the lunar surface back in 1969.

Kuiper was known to many as a man that demanded a lot of his workers, colleagues and himself. He also showed a warm-hearted side which made him popular. He eventually went into teaching, with one of his students being American astronomer Carl Sagan. Unfortunately, Gerard Kuiper passed away on the 23 December, 1973 due to a heart attack while on holiday with his wife, Sarah Fuller, in Mexico. Kuiper left behind a strong legacy of honours and accomplishments, progressing our understanding of planetary science.

> "He possessed extraordinary sight - Kuiper could apparently decipher the stars to a faint magnitude of 7.5!"

All About Space

**Future Publishing Limited**
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

**Editorial**
Editor **Gemma Lavender**
gemma.lavender@futurenet.com
☎ 01202 586209
Art Editor **Jonathan Wells**
Staff Writer **Lee Cavendish**
Production Editor **Nikole Robinson**
Photographer **James Sheppard**
Editor in Chief **James Hoare**
Senior Art Editor **Duncan Crook**

**Contributors**
Stuart Atkinson, Ninian Boyle, David Crookes, Robin Hague, Libby Plummer, Luis Villazon

**Cover images**
Adrian Chesterman, Adrian Mann, Tobias Roetsch, Jay Wong

**Photography**
Alamy; ESA; ESO; NASA; Caltech; Getty Images; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons; All copyrights and trademarks are recognised and respected

**Advertising**
Media packs are available on request
Regional Advertising Director **Mark Wright**
mark.wright@futurenet.com
Advertising Manager **Toni Cole**
toni.cole@futurenet.com
01225 687 368
Media Sales Executive **Jim Henderson**
jim.henderson@futurenet.com
01225 687 125

**International**
All About Space is available for licensing. Contact the International department to discuss partnership opportunities
International Licensing Director **Matt Ellis**
matt.ellis@futurenet.com

**Subscriptions**
Email enquiries **contact@myfavouritemagazines.co.uk**
UK orderline & enquiries **0344 848 2852**
Overseas order line and enquiries **+44 (0) 344 848 2852**
Online orders & enquiries **www.myfavouritemagazines.co.uk**
Head of subscriptions **Sharon Todd**

**Circulation**
Circulation Director **Darren Pearce**
01202 586200

**Production**
Head of Production US & UK **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Frances Twentyman**

**Management**
Commercial Finance Director **Dan Jotcham**
Creative Director **Aaron Asadi**
Art & Design Director **Ross Andrews**

**Printed by**
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

**Distributed by**
Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk Tel: 0203 787 9060

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation

**Disclaimer**
All contents © 2017 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

ISSN 2050-0548

Future is an award-winning international media group and leading digital business. We reach more than 57 million international consumers a month and create world-class content and advertising solutions for passionate consumers online, on tablet & smartphone and in print.

Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR).
**www.futureplc.com**

**Chief executive** Zillah Byng-Thorne
**Non-executive chairman** Peter Allen
**Chief financial officer** Penny Ladkin-Brand

Tel +44 (0)1225 442 244

LOSE YOURSELF IN A WORLD OF
Vinyl
FIND YOURSELF IN
OXFAM'S ONLINE SHOP
oxfam.org.uk/shop
COLUMBIA
TIME ON MY HANDS
OXFAM

# Sky-Watcher®

# AZ PRONTO & AZ5 Alt-Azimuth Telescopes

**These new lightweight and highly portable grab-and-go telescope ranges combine the thoughtfully designed and well-engineered AZ PRONTO and AZ5 DELUXE Alt-Azimuth mounts with proven high quality Sky-Watcher optics. Each model comes complete with an adjustable aluminium tripod with accessory tray and supplied with two manual flexible slow-motion cables, for easy vertical and horizontal fine motion control. Tracking is smooth and precise via their continuous worm-gear movements. The mount can also be moved around each axis manually, for rapid panning and elevation adjustments. It is often said that the best telescopes are the ones which get used most often - These new ranges are quick to assemble, extremely easy to use and are refreshingly brilliant in their convenient functional simplicity, that will encourage regular use by both beginners and seasoned observers alike!**

## AZ PRONTO ALT-AZIMUTH RANGE

**SRP £219**

*Prod.Code 10272*

**EXPLORER-130PS (AZ PRONTO)**

**130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR**

With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

**SKYMAX-102 (AZ PRONTO)**

**102mm (4") f/12.7 MAKSUTOV-CASSEGRAIN**

The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

**SRP £299**

*Prod.Code 10270*

**SRP £259**

*Prod.Code 10271*

**EVOSTAR-90 (AZ PRONTO)**

**90mm (3.5") f/10 REFRACTOR**

A classic two-element, air-spaced, multi-coated achromatic refractor. With its long focal length it is ideal for the detailed high-power study of the Moon & planets. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

**AZ PRONTO MOUNT & TRIPOD**
*Prod.Code 20317* **SRP £139**

## AZ5 DELUXE ALT-AZIMUTH RANGE

**STARTRAVEL-102 (AZ5)** *Prod.Code 10261*

**102mm (4") f/4.9 REFRACTOR**

Ideal multi-coated instrument for the widefield observation of deep-sky objects, such as nebulae, star fields, star clusters and galaxies. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

**SRP £379**

**AZ5 MOUNT & TRIPOD**
*Prod.Code 20311*
**SRP £229**

**AZ5 MOUNT HEAD ONLY**
*Prod.Code 20312*
**SRP £159**

**SRP £299**

*Prod.Code 10260*

**EXPLORER-130PS (AZ5)**

**130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR**

With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

**SRP £499**

*Prod.Code 10262*

**SKYMAX-127 (AZ5)**

**127mm (5") f/11.8 MAKSUTOV-CASSEGRAIN**

The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

**76 Page Colour Catalogue** | **Order Your FREE Copy Today** | **EMAIL: info@opticalvision.co.uk**

**Our Products are Available from Dealers throughout the UK** OVL **Please contact us, or Check our Website for your Nearest Stockist**

**OPTICAL VISION LTD**
**UNIT 3, WOOLPIT BUSINESS PARK**
**WOOLPIT, BURY ST. EDMUNDS**
**SUFFOLK IP30 9UP**

**OPTICAL VISION LIMITED**
**www.opticalvision.co.uk**

**Importers and Distributors of Sky-Watcher Astronomical Telescopes, Helios, Acuter, Barr and Stroud Binoculars & Spotting Scopes and Zenith Microscopes.**